The Growth Process in East Asian Manufacturing Industries: A Re-examination

by

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DECLARATION

This thesis was written while I was studying at the Department of Economics, Research School of Pacific and Asian Studies at the Australian National University.

Unless otherwise indicated this thesis is my own work.

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ABSTRACT

The role of TFP growth in East Asia has been intensively debated in recent years. The question of whether the East Asian economic miracles were merely driven by factors accumulation is the central theme in this debate. The role of TFP growth in East Asia is not only crucial for the future of the region but of particular importance for less developed countries, because the successful experience can serve as a model for them to follow. Regardless of its wide popularity, it has recently been questioned as to whether growth accounting is appropriate for shedding light on the role of technological progress in the 'East Asian economic miracle' achieved by Hong Kong, Korea, Singapore, and Taiwan (see, Chen, 1997, Felipe, 1999, Nelson and Pack, 1999, Rodrigo, 2000). Furthermore, the synonymous use of TFP growth with technological progress in the earlier growth accounting based studies that conclude the East Asian economies achieved insufficient progress in the level of technology is misleading.

Using the data from the UNIDO Industrial Statistics Database at the 3-digit level and the varying coefficients frontier model, this study examines whether TFP growth played a role in the manufacturing industries of Hong Kong, Japan, Korea, Singapore and Taiwan, respectively. In contrast to the stochastic frontier approach, the varying coefficients frontier model used in this study avoids the assumption of homogeneous behaviour in applying the best practice production technology. Following Nishimizu and Page (1982), the decomposition of TFP growth into technological progress and change in technical efficiency is successfully carried out. This explicitly distinguishes TFP growth from technological progress as well as recognises the importance of technical efficiency in raising TFP growth. The main findings of the thesis are summarised as follows.

First, this study finds in most cases there are certain variations in the estimated coefficients of labour input indicating different applications of their human resources; especially, the hypothesis of homogeneous industries is statistically rejected for Korea and Singapore's manufacturing industries in most years.

Second, this study finds evidence to strongly support the role of TFP growth in the manufacturing sectors of Hong Kong, Japan, Korea, and Taiwan (only for the period 1981–91). More specifically, TFP growth contributed as much as 52% to output growth

in Japan, roughly 25% in Korea and 38% in Taiwan (over the period 1981–91). On the other hand, TFP growth played no role in the Singaporean manufacturing sector. Overall, it is concluded that the average annual TFP growth of Singapore's manufacturing industries was negative over the 1970–97 period but TFP growth indeed improved in the 1980s and 1990s. Even after vigorous sensitivity tests, the result for Singapore remains pessimistic. Despite the fact that Hong Kong, Japan, Korea and Taiwan, respectively, enjoyed average annual TFP growth rates of 2.7%, 2.5%, 3.6% and 2.8% (1981–91), factors accumulation remains the most important factor in shedding light on output growth of the manufacturing sectors in the five East Asian economies.

Third, with further decomposition of TFP growth into technological progress and technical efficiency change, the latter accounted for about 30% of TFP growth in Korea and 10% in Hong Kong. Hence, to some extent, technological progress represented by the adoption of new technology has been more important in raising TFP growth for both Hong Kong and Korea's manufacturing sectors. Due to technical efficiency deterioration, TFP growth in Japan completely stemmed from technological progress. A sharp deterioration in technical efficiency was responsible for the slowdown of TFP growth in Taiwan, particularly, in the 1990s.

Finally, in contrast to tangible technology, which induces technological progress, technical efficiency improvement caused by a learning-by-doing effect may be interpreted as intangible or *efficiency-based* technology. The long-term trend analysis indicates that the Korean manufacturing sector not only upgraded technology (technological progress), but also mastered the new technology quickly (technical efficiency improvement) at the same time. This helps explain why Korean industries could maintain both technological progress and technical efficiency improvement and enjoy formidable TFP growth. For Japan, the importance of technical efficiency improvement has gradually replaced the role of technological progress in the content of TFP growth. As production technology is in a mature stage in Japan, it is conjectured that technology upgrade becomes costly, and one of the alternatives for maintaining future growth and competitiveness is to engage in improving technical efficiency. Singapore's manufacturing industries failed to enhance TFP through technical efficiency improvement. In other words, ignorance of technical efficiency enhancement largely accounted for the negative TFP growth in Singapore's manufacturing industries after the mid-1980s.

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Chapter 1

1 INTRODUCTION

1.1 THE BACKGROUND

Over the past three decades, the success of maintaining high output growth in the East Asian newly industrialised countries (NICs) of Hong Kong, South Korea (henceforth Korea), Singapore, and Taiwan has often been characterised as an economic miracle. During the 1970–97 period, the annual growth rates of GDP for Singapore, Taiwan, Korea and Hong Kong were on average 8.2%, 8%, 7.7% and 6.6% (1976–97), respectively. In terms of manufacturing output growth, Korea enjoyed the highest average annual output growth rate of 13% amongst the East Asian economies, followed by Singapore with 9.8%, and Taiwan, 8.8%.[1]

However, recent empirical studies on total factor productivity (TFP) growth, including Kim and Lau (1994), Young (1995), and Collins and Bosworth (1996), have shown that the economic miracles of these economies can be sufficiently explained by factors accumulation, i.e., labour and capital. More specifically, Kim and Lau (1994) indicate the marvellous economic record was mainly fuelled by rapid accumulation of labour and capital. Krugman (1994) even describes the East Asian economic miracle as mainly realised by perspiration with little inspiration. Using growth accounting, Young (1995) also argues that the spectacular economic performance in East Asia is not as impressive as previously thought and the economic success was nothing more than intensive factors accumulation. The implication of these findings is that such spectacular performance would soon come to an end due to little progress in TFP; namely, *economic growth would not be sustainable without TFP growth* (Solow, 1957, Denison, 1962, Jorgenson and Griliches, 1967).

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[1] Hong Kong's manufacturing sector was the only sector experiencing –0.2% output growth because of relocation of its manufacturing production to mainland China since the mid-1980s.

In contrast, studies by the World Bank (1993), Sarel (1995), Thomas and Wang (1996), Klenow and Rodriguez-Clare (1997), Hsieh (1999, 2002), and others, show that TFP growth was an important contributor to the rapid and sustained economic growth in East Asian economies.[2] Due to different data sets, methodologies with different analysis, and different sample periods covered, the existing TFP literature has revealed differing views with respect to TFP growth in East Asian countries, suggesting the role of TFP growth in the East Asian economic miracle is still inconclusive. From a policy perspective, measuring TFP growth is important as it serves as a guide for allocating resources and making investment. Thus, the importance of measuring TFP growth barely needs to be emphasized here.

Regardless of being repeatedly cited in the literature, these TFP studies questioning the role of TFP progress in the 'East Asian economic miracle' predominantly focus on the overall economy and pay little attention to manufacturing industries. Obviously, the use of aggregate data at the economy level ignores sectoral TFP performances and can hardly identify the real causes behind the theme. The report by the World Bank (1993, p. 24) points out that "export-push strategies have been by far the most successful combination of fundamentals and policy interventions and hold the most promise for other developing countries", which reinforces the significance of manufacturing industries behind the East Asian economic miracle in the past several decades.

Therefore, the earlier conclusions about the East Asian economic miracle deserve further investigations. To unveil the role of TFP growth in East Asia, it is critical to start with disaggregate industry level data, i.e., 3-digit industries. In addition, this study applies a uniform data set and a better methodology, which is described in detail in Chapter 3, to re-examine TFP growth for the manufacturing sectors of Hong Kong, Korea, Japan, Singapore, and Taiwan.

Growth Accounting

Regardless of its wide popularity, growth accounting has been seriously questioned as an appropriate means for throwing light on the role of technological progress in the 'East

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[2] Recently, Hsieh (1999, 2002) proposes the dual approach to growth accounting, which produces a contrasting results to those of Young (1995) in the cases of Singapore and Taiwan.

Asian economic miracle'. In contrast to Krugman-Young's hypothesis, Chen (1997) details the concept of TFP growth and asserts that it should not be regarded as technological change because TFP growth on the basis of growth accounting is defined as disembodied, exogenous and Hick-neutral technological change. [3] Rodrik (1998) particularly concerns about the assumption of an elasticity of substitution between labour and capital of unity for East Asian economies. If the true elasticity of substitution is less than unity, this implies that technical change is no longer Hicks-neutral and TFP growth is underestimated. Likewise, Felipe (1999) argues that an important part of technological progress is embodied in the factors of production so that conventional TFP growth may not be convincing in terms of accounting for technological progress in East Asian economies and predicting their future.

Barro (1999) reaffirms that the practice of growth accounting is only useful if the underlying technological change is independent from the production function, namely, disembodied or Hick-neutral technology.[4] Given the fact that the Solow residual derived from a production function is equivalent to the first order condition of income accounting identity, Felipe (2000) further suggests that TFP progress obtained from growth accounting cannot be interpreted as technological progress by all means. Thereby, Rodrigo (2000) points out the disembodied technology or knowledge should not be taken as technological change because most of the techniques have been incorporated into physical devises and structures.

Additionally, the assumption of perfect competition has been questioned empirically to be inadequate, which implies that factor shares will be mismeasured under the assumption of constant returns to scale (see, Hall, 1988, Morrison, 1990b, Young, 1995, p. 648).[5] Because of the monopoly profits refected in capital income, capital share will be

[3] In addition, he provides several reasons including capacity utilisation and price deflators which are likely to be responsible for the low estimated TFP growth in East Asia due to over-adjustment in factor inputs (see, Chen, 1997, pp. 32–33).

[4] Addressing the possible problems of growth accounting in conjunction with various issues, such as spillover effects, increasing returns to scale, taxes and multiple types of factor inputs, Barro (1999) offers several theoretical solutions to these issues in his paper but the empirical evidence has not yet been seen.

[5] Nelson and Pack (1999) point out that the estimates by those accumulationists are likely dependent on the extent of errors caused by the presence of biased technical change and an elasticity of substitution less than one. Felipe and McCombie (2001) have proposed constant-technology factor shares as weights to calculate the corrected growth of TFP, which avoids the above deficiencies. The TFP growth estimates over different elasticities of substitution (σ) are available in Felipe and McCombie (2001, Table 2, p. 555); for instance, if the elasticity of substitution (σ) is 0.2, the annual TFP growth rate for Taiwan will rise to 4.27%.

overstated and, in turn, labour share underestimated. As a result, the conventional growth accounting approach of measuring factor shares is invalid. Consequently, it is questionable whether growth accounting can be applied to account for the economic success in East Asia given the rapid transformation and utilisation of modern technology in the recent decades. Due to methodological and conceptual problems, the conclusions of earlier TFP studies, such as Kim and Lau (1994), Young (1995), and Collins and Bosworth (1996), remains open to debate and requires further investigation.[6]

TFP Growth versus Technological Progress

Under the framework of growth accounting, the synonymous use of TFP growth with technological progress in the earlier growth accounting based studies concludes the East Asian economies achieved insufficient progress in the level of technology. This is misleading because TFP growth not only explicitly captures technological progress but also reflects an improvement in using available resources and technology. Hence, the traditional approach of treating TFP growth as technological progress or technology advance misinterprets the nature of technological progress and ignores the importance of technical efficiency pertaining to a firm's ability to effectively use available resources. Additionally, the decomposition of output growth employed in growth accounting does not elucidate the real causes of growth nor evaluate industrial policies and government regulations from the perspective of efficiency.

To distinguish the difference, Nishimizu and Page (1982) first incorporate the concept of technical inefficiency into the production process and decompose TFP growth into technological progress and technical efficiency change; namely, TFP growth stems from a combination of technological progress and technical efficiency improvement. Technological progress coming from innovation and technological diffusion is measured by a shift in the potential production frontier from one period to another. Technical efficiency change reflects the movement of a firm's actual output to frontier output,

[6] Using a similar methodology of growth accounting, empirical results frequently differ. In terms of country-specific studies, the extent of TFP growth in Singapore appears the most controversial. According to Sarel (1995), Collins and Bosworth (1996) and Klenow and Rodriguez-Clare (1997), the results of annual TFP growth rates for Singapore were 2% (nearly), 1.5% and 3.3% over the 1975–90, 1960–94, and 1960–85 periods, which substantially contradicts Young (1995) that Singapore had little progress (0.2%) in TFP during the period 1966–90.

where the distance between actual output and potential output, or production frontier, is traditionally referred to as technical inefficiency.

Conventional Stochastic Frontier versus Varying Coefficients Frontier Model

In addition to growth accounting, a large number of econometric approaches in the literature have so far been suggested for measuring TFP growth. These estimations and specifications of production frontier or 'best practice' production function are well documented in several survey articles, such as Førsund, Lovell, and Schmidt (1980), Bauer (1990), Coelli (1995) and Kalirajan and Shand (1999).

Even though the conventional stochastic production frontier approach proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) distinguishes TFP growth from technological progress, the assumption of the homogeneity of firms or industries in applying frontier production technology remains unwarranted. Using the varying coefficients frontier model proposed by Swamy (1970, 1971) and Kalirajan and Obwona (1994), this study estimates potential production frontier to investigate TFP growth for the East Asian manufacturing industries.[7] The major differences between these two approaches lie in the underlying assumptions and estimations of production frontier. The strengths of the varying coefficients frontier model are succinctly outlined as follows.

The estimation of conventional stochastic frontier is carried out by assuming that firms are homogeneous in terms of applying the best available technology. However, in practice, firms utilise the frontier production technology differently for a variety of reasons regardless of the best practice technology being available to all. With various firm-specific characteristics, firm *A* may use its labour input most efficiently because of extensive experience in choosing and supervising its human resources while firm *B* is neither efficient in using its labour force nor capital input. Yet, firm *C* may be good at utilising and managing its capital input for some reason. As a result, it is empirically observed that firms with the same level of inputs achieve different levels of output while facing the same production technology.

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[7] The varying coefficients frontier model provides an convincing reason to explain why output differs across firms not only due to their degree of inefficiency but also to the different applications of the best practice production technology.

Moreover, the conventional stochastic frontier approach captures the variations in intercept only and leaves the estimated coefficients of factor inputs remaining to be constant, this is, a neutral shift of production frontier. To eliminate the above deficiencies, this study frees the conventional frontier model from the restrictive assumption that all firms homogeneously apply the frontier production technology. The application of the varying coefficients frontier approach facilitates the modelling of a non-neutral shift from the average production frontier, which explicitly captures the variations in intercept as well as the estimated coefficients of factor inputs and, hence, represents a significant methodological improvement.

1.2 OBJECTIVES OF THE THESIS

Several East Asian countries, Hong Kong, Korea, Singapore and Taiwan, have achieved an economic miracle of maintaining high economic growth over the past several decades prior to the Asian financial crisis. However, Kim and Lau (1994), Krugman (1994), and Young (1992, 1995) have recently cast doubts on this economic success. They claim that the successful achievement will virtually come to an end due to lack of significant TFP growth. Given methodological limitations and differences in underlying assumptions, it is difficult to come to a consensus and conclude solidly from any previous analyses. Hence, using the varying coefficients frontier model and panel data from the United Nations Industrial Development Organisation (UNIDO) Industrial Statistics Database, the overall objective of this study is to re-examine the role of TFP growth and identify the sources of output growth in the context of manufacturing industries for the five East Asian economies. A number of specific issues are:

- to explain why TFP growth differs from technological progress, which implicitly rejects the use of growth accounting while investigating the process of technological progress in East Asian manufacturing industries;
- to demonstrate why this study favours the use of the varying coefficients frontier model rather than the conventional stochastic frontier approach;
- to statistically test whether manufacturing industries in East Asia homogeneously applied the best practice production technology on the basis of the Breusch-Pagan Lagrange Multiplier (LM) test;

- to investigate the concern of TFP growth slowdown in East Asian manufacturing sectors;
- to link the possible relationships between technological progress (or technical efficiency change) and structural transformation;
- to compare TFP growth between high-tech and low-tech industries on the basis of two proposed hypotheses; (First, the conjecture of high-tech industries gaining more TFP growth is investigated. Second, on examining the sources of TFP growth, the hypothesis is explored that high-tech industries gain TFP growth mainly through technological progress and low-tech industries from technical efficiency improvement.)
- to perform a number of sensitivity tests to consolidate the findings of this study and a comparison with earlier TFP studies for each economy.

1.3 ORGANISATION OF THE THESIS

The remainder of the thesis is organised as follows. Chapter 2 reviews recent TFP studies of the manufacturing sectors in the five East Asian economies. The central theme of the review focuses mainly on the estimates of TFP growth rates, sample periods covered, and estimation approaches used in previous studies. Due to different aggregations and sample periods, the number of manufacturing industries examined varies from study to study. A brief conclusion will be drawn at the end.

Chapter 3 discusses several popular methodologies of measuring TFP growth, including the conventional stochastic frontier, and meta-production function and stresses the need for alternative approaches. This is followed by discussion of a recent methodology of the varying coefficients frontier model. Next, the decomposition analysis is demonstrated in which output growth can be decomposed into input growth, technical efficiency change and technological progress. More importantly, the decomposition of TFP growth is particularly helpful from the policy perspective. The empirical model, associated tests, data sources, variables constructions and selection of deflators are also presented.

Chapter 4 first describes the characteristics of the five East Asian manufacturing sectors. Using the Breusch-Pagan Lagrange Multiplier (LM) test, the conventional assumption of the homogeneity of manufacturing industries is examined. In addition, it shows the estimated frontier, mean coefficients and computer program used in this study. Applying the concept of technical efficiency, how well manufacturing industries in the East Asian economies utilised labour and capital inputs is also discussed. Finally, the number of industries and sample periods covered are thoroughly discussed in the Appendix.

Chapter 5 identifies the sources of output growth and analyses the importance of TFP growth in different stages of economic growth in the East Asian manufacturing sectors. The average share of industries in the manufacturing sector is concisely discussed prior to presenting the decomposition results of long-term output growth. The detailed annual TFP growth estimates for individual industries are presented and trends of annual TFP growth for the five manufacturing sectors discussed.

In Chapter 6, following Nishimizu and Page (1982), TFP growth for the five East Asian manufacturing industries is decomposed into contributions due to technological progress and technical efficiency change, which explicitly distinguishes TFP growth from technological progress. This is followed by an analysis of the long-term trends of technical efficiency change and technological progress providing empirical evidence with regard to structural transformation across East Asian manufacturing sectors.

Two hypotheses for high-tech and low-tech industries are examined. First, this study compares the productivity growth of high-tech with low-tech industries to examine whether high-tech industries have higher TFP growth. Second, the hypothesis is examined that the sources of TFP growth for high-tech industries come largely from technological progress and for low-tech industries mainly from technical efficiency improvement. A series of sensitivity tests for Singapore's manufacturing sector and comparisons with earlier TFP studies are carried out. The final chapter summarises the main findings of this study, presents the limitations of this research, and offers policy implications.

Chapter 2

2 LITERATURE REVIEW: TFP STUDIES ON EAST ASIAN MANUFACTURING INDUSTRIES

Before proceeding to the empirical model, this chapter briefly reviews recent TFP studies on East Asian manufacturing sectors. The central theme of the review focuses mainly on the estimates of TFP growth rates, sample periods covered, and estimation approaches used. The review begins with TFP survey papers before shifting to country-specific TFP studies, beginning with East Asian manufacturing sectors, followed by Hong Kong, Japan, Korea, Singapore, and Taiwan. Detailed comparisons in terms of TFP growth estimates at the industry level will be carried out in Chapter 6. Due to different aggregations and sample periods, the number of manufacturing industries examined will vary from study to study. A brief conclusion will be drawn at the end.

2.1 TFP SURVEYS

Chen (1997) discusses the popular TFP methodologies and raises concerns over possible problems in measuring capital input. [8] He argues that the assumption of disembodied technology appears to be problematic in the case of Singapore, which may have gained much more from embodied technological change than disembodied technological change due to the fast-improved quality of the labour force and the adoption of modern technologies. The persuasive conclusion by Chen (1997) states that '*the significance of technological change in economic growth depends largely on how TFP is defined and how factor input data are measured*'.

Extending Chen's (1997) arguments, Felipe (1999) reiterates the theoretical and empirical problems of the recent TFP literature with respect to the application of aggregate production and growth accounting. Given the various conflicting results, Felipe

[8] A number of reasons for the possible over-adjustment of factor inputs in East Asia include capacity utilisation, depreciation of the capital stock, the deflators of capital input, and so on. For the details of other possible reasons, see Chen (1997, pp. 32–33).

urges caution in drawing any conclusions from a vague TFP estimate because of the surrounding problems and limitations implied by TFP methods. To avoid misuse of the notion of TFP growth, he points to several tasks for future research such as understanding technological change and interaction between human and physical capital.

Barro (1999) presents an extensive examination of growth accounting and demonstrates several possible problems for models with increasing returns and spillovers, various kinds of taxes or different types of factor inputs. He also shows that the growth accounting exercise can even be expanded to endogenous growth theory, such as product-varieties and quality-ladders models.[9] In a comprehensive study of TFP, Hulten (2000) broadly discusses methodologies and indicates possible extensions for future research in the wake of new growth theory. Despite the drawbacks of growth accounting, Hulten praises the idea of a TFP residual that has provided a simple and internally consistent intellectual framework for organising data on economic growth and the theory to guide economic measurement.

2.2 REVIEW FOR EAST ASIA

Prior to reviewing country-specific TFP studies, this section discusses studies that have compared TFP performance across East Asian manufacturing sectors.[10] Using growth accounting with translog production function, Young (1995) examines TFP growth in the four East Asian Tigers (Hong Kong, Korea, Singapore and Taiwan) while the results for manufacturing sectors are available only for the last three economies. On the one hand, he finds evidence that the Korean manufacturing sector gained TFP at an average annual rate of 3.0% over the 1966–90 period while the average annual TFP growth rate for Taiwan's manufacturing sector was moderate at 1.7% between 1966 and 1990, due mainly to zero TFP progress in the 1970s. On the other hand, Singapore's manufacturing sector was reported to have had a TFP decline of 1% during the period 1970–90 on an average annual basis.

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[9] In this case, TFP growth becomes the sum of exogenous technological change and endogenous expansion of varieties (or growth rate of overall quality) weighted by the labour share.

[10] Apart from Young (1995), none of these TFP studies on East Asian manufacturing sectors have taken embodied technology into account, namely, adjusting quality improvement embodied in capital and labour inputs. Thus, without carrying out the quality improvement adjustments those TFP estimates are likely to be overstated.

In a study of manufacturing sectors in Korea, Turkey, Yugoslavia and Japan (as a comparator) by Nishimizu and Robinson (1984), the TFP of Korean and Japanese manufacturing sectors measured by the translog TFP index number grew by 3.71% and 2.04% over the periods 1960–77 and 1955–73, respectively. In terms of contribution to output growth, 20.7% and 17.6% were attributed to TFP growth. As for 16 individual industries, the electrical machinery gained the highest average annual TFP growth of 7.25% (Korea) and 4.42% (Japan). Yet, outcomes varied substantially across other 15 industries between these two economies.

Nadiri and Kim (1996) estimate TFP growth for the U.S., Japanese, and Korean manufacturing sectors. Using the Törnqvist index with labour, capital, materials and R&D as factor inputs, the average annual TFP growth for Korea and Japan based on total cost shares as weights was 0.69% and 1.26%, respectively, over the 1975–90 period. They also provide another set of TFP estimates if the conditions of perfect competition, constant returns to scale, and instantaneous adjustment of all inputs are assumed to be valid. The average annual TFP growth rates based on revenue shares as weights for Korean and Japanese manufacturing sectors were 1.14% and 3.15%, respectively.

In applying growth accounting to the four Asian manufacturing sectors of India, Indonesia, Korea and Taiwan, Timmer and Szirmai (2000) estimate the aggregate and output-weighted TFP growth, respectively. The difference between the two TFP growth estimates is the result of a total reallocation effect due to the shift from less productive manufacturing industries towards more productive industries. Their results show that the average annual TFP growth rate of the Korean manufacturing sector was 4.5% over the period 1963–90 regardless of a negative reallocation effect. For Taiwan's manufacturing sector, it was 2.0% for the 1963–93 period, which was in part attributable to the reallocation effect (0.3%).

Taking the manufacturing sector of the United States as the reference country, Timmer (2002) argues that in 1997 the TFP level of Taiwanese manufacturing was 34% relative to that of the United States in 1997, due to the rapid introduction of new technologies, leading to little time for efficient assimilation. That is, Taiwan gained little from technical efficiency improvement.

Han, Kalirajan and Singh (2002) apply the varying coefficients model to investigate TFP growth for 20 manufacturing industries in Hong Kong, Korea, Japan and Singapore. After decomposing output growth into input growth, technical efficiency and technological progress, it is suggested that over the period 1987–93 factors accumulation accounted for most of the output growth in the four East Asian manufacturing sectors while technological progress played little role during the same period.[11] A summary of these TFP studies on East Asian manufacturing sectors is presented in Table 2.1.

Table 2.1 TFP studies on East Asian manufacturing sectors

Authors	Country	Period	Method	TFPG p. a. (%)
Nishimizu & Robinson (1984)	Japan	1955–73	translog TFP index	2.04
	Korea	1960–77		3.71
Young (1995)	Korea	1966–90	growth accounting	3.0
	Singapore	1970–90		-1.0
	Taiwan	1966–90		1.7
Nadiri and Kim (1996)	Japan	1975–90	Törnqvist index	1.26
	Korea	1975–90		0.69
Timmer and Szirmai (2000)	Korea	1963–90	growth accounting	4.5
	Taiwan	1963–93		2.0

Note: Nadiri and Kim (1996) also provide another set of TFP growth estimates for Japan and Korea if the conditions of perfect competition, constant returns to scale, and instantaneous adjustment of all inputs are assumed to be valid.

2.3 REVIEW FOR HONG KONG

Compared with other East Asian manufacturing sectors, there have been relatively fewer TFP studies on Hong Kong's manufacturing sector because most TFP studies involving Hong Kong concentrate on the overall economy, for instance, Dowrick and Nguyen (1989), Kim and Lau (1994), Young (1992, 1995), Sarel (1995), Drysdale and Huang (1997), and Hsieh (1999, 2002).

The closest study to this present theme is that by Kwong, Lau and Lin (2000). Using growth accounting with translog gross output function, they investigate the TFP growth

[11] Although this study is concurrently conducted with Han, Kalirajan and Singh (2002), the coverage of sample periods and manufacturing industries in this study is much longer and larger than Han *et al.* (2001). Besides, the various adjustments including quality improvements in labour and capital and the choices of deflators are seriously considered. An important partner of East Asia, Taiwan, is also included in this study.

of Hong Kong's manufacturing industries for the period 1984–93. Irrespective that 15 out of 29 industries gained progress in TFP, the overall manufacturing sector, surprisingly, experienced a technology decline of 13.8% during the decade.[12] Put differently, Hong Kong's manufacturing sector in 1993 could only produce 87% of the output in 1984 from the same amount of resources.[13] The interpretation for the unexpected finding is that it had much to do with the liberalisation in China since 1978 and the style of Hong Kong's manufacturing sector (original equipment manufacturing). More specifically, manufacturers in Hong Kong were not willing to invest heavily in research and development (R&D) to upgrade their technology if the low-cost resources facilities in mainland China could be easily accessed and making profits remained very positive.

Tuan and Ng (1995) explore three major export-oriented industries, garments and wearing apparel, consumer electronics, and electronics parts and components. In applying the Cobb-Douglas production function with regression approach, it is found that there was little change in TFP level in the three industries except for garments and wearing apparel.[14]

Imai (2001) does not explicitly estimate TFP growth for Hong Kong manufacturing sector. Instead, he disaggregates Hong Kong's economy into three sectors, non-tradable, tradable services and tradable goods (overwhelmingly dominated by manufacturing). Applying growth accounting, it is suggested that high average annual TFP growth rates of the tradable goods sector (manufacturing) were 5.6% and 6.0% for the 1981–90 and 1991–97 periods, respectively.[15]

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[12] Sample periods differ across 29 industries, for example, the petroleum and coal industry is from 1988–93 and the electronic parts and components industry from 1984–89. For more details, see Table 6.11.

[13] One possible concern is that Kwong *et al.* (2000) use gross output (rather than conventional value added) with the inputs of material, labour, capital, utilities and factory space to estimate TFP growth because they claim that manufacturing value added was overstated as a result of the recent integration with mainland China in manufacturing production. An example is provided in Kwong *et al.* (2000, p. 173, footnote 4).

[14] Strictly speaking, the study by Tuan and Ng (1995) is less relevant to the objective of this study. Moreover, it is unclear why there were several negative capital coefficients in their estimation results. This indicates that less capital would lead to more output, which basically contradicts the economic theory. No explanations were mentioned regarding the huge swing in TFP level and capital coefficients (or elasticities) on an annual basis, say, from 1.6977 to 2.9047 (constant term, represented by TFP) and from 0.2618 to 0.6300 (capital coefficient). Hence, their results must be read with great care.

[15] Note that the qualitative improvement associated with labour and capital inputs was not eliminated in Imai's study, which may overstate the actual TFP growth rates. More importantly, the tradable sector cannot be completely viewed as the manufacturing sector; hence, his result should be interpreted with caution.

2.4 Review for Japan

There are many TFP studies in the literature on Japanese manufacturing industries, which enables them to be classified into four categories. The first category concentrates on individual or single industry, e.g., chemical or automobile industry. Using the translog (Törnqvist) index of cost efficiency growth to measure TFP growth, Fuss and Waverman (1990) investigate productivity growth in the motor vehicle industry of Canada, Japan and the US. They find that the TFP of the Japanese auto industry grew by an annual rate of 3.0%, compared with an average annual TFP growth rate of 1% for the U.S. and Canada.[16] In terms of the sources of TFP growth, 80% of growth in the Japanese auto industry was due to technical change and 20% to scale economies during the 1970–84 period.

Kumbhakar, Nakamura, and Heshmati (2000) discuss the time trend model and the variants of the general index model to accommodate technical change and technological biases in measuring TFP growth. They show that the average annual TFP growth rates computed by three versions of the general index model appeared to be similar ranging from 1.553% to 1.716% for the Japanese chemical industry during the period 1968–87.

The second category focuses on either the Japanese manufacturing sector as a whole or disaggregate manufacturing industries. Nakajima, Nakamura and Yoshioka (1998) use an index number approach to estimate and decompose TFP growth into technical change and scale economy effects for 18 manufacturing industries over the period 1964–88. They find that more than 90% of the gains in TFP were due to technical change and average annual TFP growth rates ranged from 2.167% (food/kindred products industry) to 5.489% (petroleum and coal product industry). Overall, the simple average of TFP growth rate for the entire manufacturing sector was 3.731% per annum.

A study of analysing the sectoral shifts in the Japanese economy by Prasad (1997) finds that the share of manufacturing output in the real economy GDP remains stable despite the declining share of the manufacturing sector in total employment. According to

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[16] Because TFP growth measures the improvement in the efficiency of the use of inputs over time, Fuss and Waverman (1990) measure TFP growth by the growth in cost efficiency.

the OECD sectoral database, the average annual TFP growth rate of manufacturing sector during the 1971–93 period was 2.8%.

In an overall assessment of the Japanese economy, Sato (2002) characterises the contraction of manufacturing employment as partly contributed to the stagnant economy in the 1990s. The average annual TFP growth rates for the manufacturing sector were found to be 2.5%, 2.6% and 2.2% over the periods 1979–85, 1985–91 and 1991–97, respectively.[17] Yet, the poor performance of the non-manufacturing sector was the main cause that pulled down overall productivity growth in the 1990s.

The success of Japanese industrialisation after World War II attracts much attention in comparing the Japanese growth experience with other industrialised nations. If the U.S. manufacturing sector is assumed to be the world leader in terms of production technology, an interesting question is to examine the extent of catching-up progress its Japanese counterpart has made over the past several decades. Hence, the third category discusses a bilateral comparison between Japanese and U.S. manufacturing industries.

Norsworthy and Malmquist (1983) initially reject the value-added approach to measure productivity growth in the U.S. and Japan due to the failure of separability tests.[18] Then, the comparison of the estimates of multifactor productivity growth for U.S. and Japanese manufacturing was carried out using the translog production function and gross output approach. Average annual TFP growth rates for Japanese manufacturing during the 1965–73 and 1973–78 periods were found to be 0.91% and 1.64%, respectively.[19]

Jorgenson, Kuroda and Nishimizu (1987) employ translog quantities indexes of the rates of technical change to compare productivity growth of Japanese and U.S. manufacturing industries. The empirical results show that the estimated average annual TFP growth rates for 21 Japanese manufacturing industries varied widely from –3.16% in

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[17] The estimates of TFP growth rates of Sato (2002) are from the *Annual Report of National Accounts* by the Japanese Economic Planning Agency.
[18] Using the same data set of Norsworthy and Malmquist (1983) and non-parametric analysis, Chavas and Cox (1990) suggest the findings of Norsworthy and Malmquist (1983) are sensitive to their parametric specification. In other words, Chavas and Cox (1990) find little evidence to support the necessity of using the gross output approach and the hypothesis of Hick non-neutral technical change.
[19] If the value-added approach were applied, the corresponding results would be 2.03% and 3.67%, respectively.

the petroleum and coal industry to 3.07% in the electrical machinery industry over the period 1960–79. The modest annual TFP growth rate of 0.83% for the overall manufacturing sector was due largely to the TFP slowdown after 1973.

Griliches and Mairesse (1990) use firm-level data to assess the contribution of R&D to productivity growth in the manufacturing sectors of Japan and the U.S. By assuming that value added and sales vary proportionally and capital input share is constant and equal to 0.25 for all firms in Japan, the electrical equipment and instruments industries experienced the highest annual TFP growth rates during the 1973–80 period of 8.4% and 8.1%, respectively.[20] On the other hand, the lowest average annual TFP growth rate of 0.6% was reported in the chemical and rubber industry.

Finally, the last category concentrates on a wider and international comparison of Japanese manufacturing industries with other industrialised manufacturing such as the U.S., Canada, and Germany. Using the generalised Leontief cost function, Morrison (1990a) provides an alternative measure of TFP growth, which allows for scale economies, subequilibrium, costs of adjustment and markup behaviour, as opposed to the conventional TFP growth approach. The comparison of these two approaches is demonstrated using the data of the U.S., Japanese and Canadian manufacturing sectors. The average annual conventional TFP growth rate of the Japanese manufacturing sector was 1.223% over the period 1960–81 but the modified TFP growth rate became 0.987%.

Using a Törnqvist TFP index, Denny *et al.* (1992) find the evidence that the slowdown of TFP growth was a widespread phenomenon across the manufacturing sectors of Canada, Japan and the U.S. over the 1973–80 period. For Japanese manufacturing industries, average annual TFP growth rates ranged from 0.23% in the food industry to 3.28% in precision instruments during the 1954–86 period. Moreover, there was no sign of any improvement in TFP growth in Japan in the 1980s.

[20] The results of the Japanese manufacturing industries in Griliches and Mairesse (1990) are unweighted firm averages and many of multinational firms are also included in the sample, so TFP growth estimates are not comparable to other studies.

2.5 Review for Korea

One of the key issues in the series of TFP studies on the Korean manufacturing sector by Jene K. Kwon is the consideration of capital utilisation rate.[21] After incorporating the capital utilisation rate in the growth accounting framework, Kim and Kwon (1977) demonstrate that the contribution of TFP growth to output growth in the Korean manufacturing sector was significantly reduced from 36% to 8% during the period 1962–71. Unfortunately, the detailed estimate of TFP growth is not available in their study.

Kwon (1986) decomposes TFP growth into technical change, non-constant returns to scale, and change in capital utilisation by linking growth accounting to a cost function. The empirical result shows that during the 1961–80 period TFP of the Korean manufacturing sector grew by 2.95% per annum and 15.16% of output growth was attributed to TFP growth. More specifically, the shares of contribution to TFP growth by technical change, non-constant returns to scale, and change in capital utilisation were found to be 44.6%, 38.1% and 17.3%, respectively.

In employing growth accounting, Dollar and Sokoloff (1990) decompose labour productivity growth into capital deepening and TFP growth and analyse the relative contributions to labour productivity growth in 25 Korean manufacturing industries. They find evidence that capital deepening accounted for over 70% of labour productivity growth in heavy industries comprising iron and steel, industrial chemical and others. By contrast, labour productivity growth in light, medium, and natural resource industries on average explained about two-thirds of labour productivity growth.[22] The highest TFP growth was found in the leather (12.7%) and other chemical (12.6%) industries but the glass industry suffered a negative growth rate of 4.1%. Among TFP studies on Korean manufacturing industries, Dollar and Sokoloff (1990) offer the highest average annual TFP growth of 6.1% for the entire manufacturing sector over the period 1963–79.

Kang and Kwon (1993) measure the TFP growth of 22 Korean manufacturing industries using growth accounting associated with a translog cost function and taking

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[21] Other papers on the issue of the Korean manufacturing sector's productivity growth by Jene K. Kwon include Kwon (1986), Kang and Kwon (1993), Park and Kwon (1995) and Yuhn and Kwon (2000).

[22] The classification of four major categories (light, heavy, medium and natural resource) is available in Dollar and Sokoloff (1990, p. 313).

account of capital utilisation rate. They suggest that the TFP of the entire manufacturing sector on average grew at annual rates of 3.43% and 0.16% for the periods 1963–73 and 1973–83, respectively. Input growth accounted for 84% and 99% of the output growth for the two corresponding periods, suggesting that the output growth in Korean manufacturing industries was mainly input-driven. Meanwhile, the decomposition of TFP growth into technical change, returns to scale and capital utilisation shows that returns to scale accounted for half of the TFP growth and technical change contributed 45% during the 1963–83 period.

In applying a Cobb-Douglas production function and value added as a measure of output, Pilat (1995) first compares the TFP level of Korean manufacturing with that of the United States based on specific industry of origin purchasing power parities. Korean manufacturing's total factor productivity has risen from 9% of the U.S. level in 1967 to more than 18% in 1987. Using growth accounting, Pilat finds the TFP growth of overall manufacturing exhibiting an average annual rate of 4.3% between 1967 and 1987. Among 13 Korean manufacturing industries, the highest average annual TFP growth rate of 10.4% occurred in the electrical machinery and equipment industry.

Using the short-run generalised Leontief cost function, Park and Kwon (1995) investigate the TFP growth of 28 Korean manufacturing industries, grouped as heavy and light industries, along with the effects of markups (market power), scale economies and capacity utilisation. The empirical results show that there was a considerable difference between conventional TFP growth (2.0%) and generalised TFP growth (–1.6%) for Korean manufacturing as a whole over the period 1967–89. Due to the failure of distinguishing the effects of scale economies and capacity utilisation from the TFP measures, the conventional TFP estimates are theoretically biased. Hence, it is argued that the negative TFP growth derived from the generalised TFP measure genuinely reflects the true degree of the Korean technology decline in manufacturing industries.

In addition to exploring the impact of government interventions (tariff, tax incentives etc.) on the TFP growth of the manufacturing sector in Korea, Lee (1996) also provides TFP growth estimates for 38 manufacturing industries over four separate periods, 1962–67, 1968–72, 1973–76 and 1979–83. As there is no aggregate TFP growth estimate for the entire manufacturing sector and no estimates for 38 industries over the entire period, the results for individual industries are not presented here but are available in Lee (1996, p. 408).

In a comparative study involving Korea and Taiwan, Okuda (1997) provides TFP growth estimates for Korean manufacturing industries under the framework of growth accounting. The Korean manufacturing sector as a whole had an average annual growth rate of 3.2% in TFP for the period 1970–93. In terms of relative contribution to output growth, 22.7% of output growth was attributed to TFP growth during the sample period. Moreover, the first and second highest annual TFP growth rates appeared in the metals (8.4%) and machinery (7.6%) industries; in contrast, the oil refinery industry did not record any progress in TFP.

Lee, Kim and Heo (1998) apply the non-parametric Malmquist productivity index for 36 Korean manufacturing industries over the period 1967–93. Overall, the TFP of the entire manufacturing sector increased by an annual rate of 0.286%. The decomposition of TFP growth reveals that technological progress (1.141% per annum) was the major source of TFP progress. However, the moderate technological progress along with low TFP growth implies that there was deterioration in technical efficiency (–0.855% per annum) over time, which was the case for most Korean manufacturing industries.

Hwang (1998) disagrees with the views of Young (1995) and others who argue that TFP performance in East Asian manufacturing sectors was comparable with that of developed countries. Applying two different approaches (the conventional growth accounting and augmented Solow model), Hwang shows that TFP for Korea's entire manufacturing sector increased by average annual rates of 2.06% and 2.46%, respectively, between 1973 and 1993.[23] Further applying Johansen's cointegration analysis suggests that the Korean manufacturing sector can be characterised by an endogenous growth model due to increasing returns to scale in production technology or a learning-by-doing effect.

Following Hall (1988) and Harrison (1994), Kim (2000) distinguishes the difference between 'standard' TFP growth and 'true' TFP growth for 36 Korean manufacturing

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[23] Hwang (1998) uses the index of manufacturing output as a measure of aggregate output and the total man hours worked in the Korean manufacturing as a measure of labour input.

industries over the period 1966–88 due to imperfect competition and non-constant returns to scale. Using Korea's *Input Output Tables* and adjusting the growth in labour input for changes in hours worked and education level, the result derived from the traditional growth accounting shows that the unweighted average TFP growth of Korean manufacturing industries was 1.9% per annum. Furthermore, after excluding imperfect competition and non-returns to scale effects, the true unweighted TFP growth estimate of the entire manufacturing sector was about 0.5% per annum during the sample period, accounting for only 3% of output growth in Korean manufacturing industries. The detailed TFP growth rates for 36 manufacturing industries are available in Kim (2000, p. 77, Table 7).

Kwack (2000) measures the TFP growth of Korean manufacturing industries over the period 1971–93. Using the growth accounting approach, the results reveal annual TFP growth rates of 3%, 4.5%, and 1.1% in the total, heavy, and light manufacturing industries. The contribution of TFP growth to value added growth for the entire manufacturing industries was 21.6% for the sample period but has been slowing down to 9.4% in the recent period 1989–93.

Yuhn and Kwon (2000) extend the work of Kwon and Yuhn (1990) and criticise the use of value added as a measure of manufacturing output in any productivity analysis due to the failure of satisfying separability hypotheses. Then, they apply the growth accounting approach to estimate TFP growth of the Korean manufacturing sector as a whole. The result suggests that TFP grew by an average annual rate of 1.52% between 1962 and 1981 and the contribution of TFP growth to output growth was merely 7.6%.

Kim and Han (2001) examine the TFP growth of Korean manufacturing industries by using a stochastic production frontier approach. Following Kumbhakar (2000), TFP growth is decomposed into four components: technical progress, changes in technical efficiency, changes in allocative efficiency and scale effects. Using the annual data for 508 manufacturing firms listed in the Korean Stock Exchange from 1980 to 1994, they found that technical progress was a key contributor to TFP growth and technical efficiency improvement also provided a significant effect on TFP growth. The average annual TFP growth rate of the entire manufacturing sector was 7.3% despite the decreasing trend. Among the industries, the fabrication industry enjoyed the highest average annual TFP growth of 9.4% during the same period, followed by textiles (7.7%) and food (7.1%).

2.6 Review for Singapore

There have been many TFP studies on Singapore's manufacturing industries. A comprehensive survey by Mahadevan (1999) in addition offers comparisons of TFP performance in the service sector and the overall economy. Notably, Tsao (1985) first argues that the miraculous output growth in Singapore's manufacturing industries was not associated with high TFP growth in the 1970s. In applying growth accounting with translog production function and four factor inputs, Tsao discovers that 17 out of 28 Singapore's manufacturing industries experienced negative TFP growth over the period 1970–79. On average, Singapore's manufacturing sector enhanced its TFP by only 0.08% per annum stemming from annual TFP growth rates of –1.18% for the period 1970–73 and 0.71% for 1973–79.

Wong and Gan (1994) apply the conventional growth accounting approach examining TFP growth in 28 Singapore manufacturing industries at the 3-digit level. Using gross output and four factor inputs of capital, labour, material and energy, their results indicate that the overall manufacturing sector enjoyed an average annual TFP growth rate of 1.6% over the period 1981–90. Startlingly, the high-tech industries such as electrical machinery and electronic products, and industrial machinery, respectively, experienced a TFP decline of 0.54% and 2.32% annually, while the tobacco industry obtained the highest average annual TFP growth rate of 11.22%. Moreover, Wong (1993) investigates the sources of labour productivity growth and finds that the TFP growth of Singapore's manufacturing industries accounted for 44% of labour productivity growth in the 1980s.

Rao and Lee (1995) explore the sources of output growth in Singapore's manufacturing and services sectors and the overall economy by separating three distinct phases, 1966–73, 1976–84, and 1987–94. In employing conventional growth accounting, their findings show that Singapore's manufacturing sector gained an average annual TFP growth of –0.4% and 3.2%, respectively, for the periods 1976–84 and 1987–94. The contribution of TFP growth to output growth increased from –5% to 32% between the two periods. In contrast to Kim and Lau (1994) and Young (1995), they conclude that the sustainability of Singapore's manufacturing sector looks optimistic.

Leung (1997) employs growth accounting to study 30 Singapore's manufacturing industries for the period 1983–93. Unlike most existing TFP studies, Leung estimates the weighted average annual TFP growth of 2.8% for the manufacturing sector as a whole. In addition, the average annual TFP growth rate of the aggregate (unweighted) manufacturing sector was calculated to be 2.0%. Hence, he suggests that an average annual TFP growth rate of between 2% and 3% is plausible for Singapore's manufacturing during the decade. With the further analysis of the determinants of TFP growth, a learning-by-doing effect was strikingly found not to be linked with TFP growth. Leung's result implicitly confirms the finding of this study indicating no technical efficiency improvement in Singapore's manufacturing industries.

Bloch and Tang (1999) estimate cost-saving technical progress for 27 of Singapore's manufacturing industries at the 3-digit level in an attempt to distinguish TFP growth derived from conventional growth accounting. Apart from the divergence of eight industries, the findings of 19 industries indicate that 11 industries experienced technical progress represented by the elasticity of cost with respect to time while the other eight industries suffered technical regression between 1975 and 1994. With regard to individual industries, the fast growing industry, electronic product and components, significantly gained technical progress of 6.5% per annum. Moreover, 17 out of 19 industries exhibited increasing returns to scale. It is also suggested that the largest and fastest growing industries such as electronic products and components are inclined to demonstrate a higher rate of technical progress but a greater degree of decreasing returns to scale. The estimates of TFP growth rates computed by growth accounting are also available in their study.

Additionally, Mahadevan and Kalirajan (2000) apply the stochastic production frontier to examine TFP growth for 28 Singapore's manufacturing industries over the period 1976–94. Although input growth emerges as a major factor driving output growth, they find evidence of positive technological progress with negative technical efficiency change leading to positive but low and declining TFP growth in Singapore's manufacturing sector. The average annual TFP growth rates for the periods 1976–84 and 1987–94 were 0.92% and –0.52%, respectively. More specifically, the –0.52% TFP growth rate was attributable to –0.8% technical efficiency change and 0.28% technological progress.

2.7 REVIEW FOR TAIWAN

Before discussing the relationship between export performance and productivity growth, Chen and Tang (1990) apply growth accounting to estimate TFP growth for 16 Taiwan manufacturing industries at the 2-digit level over the 1968–82 period. Unlike conventional growth accounting, the TFP growth in their study is defined as 'a change in average cost not accounted for by the changes in input prices', in which the inputs include labour, capital and material. They find that four of the 16 industries experienced negative TFP growth and average annual TFP growth ranged from –0.76% in the lumber and furniture industry to 4.13% in leather and fur. It should be noted that it is unclear whether quality improvement embodied in capital and labour inputs has been adjusted in their study.

Okuda (1994) explores the impact of trade and foreign direct investment on productivity growth in Taiwan's manufacturing industries and using a Törnqvist index provides TFP growth estimates for 11 industries between 1978 and 1991.[24] The average annual TFP growth rate for the entire manufacturing sector was estimated at 2.6% during the sample period. In terms of individual industries, the electronics industry outperformed other industries with 5% annual TFP growth. Note that the adjustments of quality improvement embodied in labour and capital inputs have not been carried out in Okuda's study suggesting a possible overstatement of TFP growth. Okuda (1997) extends his earlier study to compare the TFP performance of the Taiwanese and Korean manufacturing industries. However, the sample period covered for Taiwan's manufacturing industries only adds one more year to his earlier study from 1978 to 1992. In addition, looking at the new TFP growth estimates in Table I of Okuda (1997, p. 365), they are generally comparable to his previous results; hence, the review of Okuda (1997) will not be repeated here.

The importance of the decomposition of factor inputs is explicitly stressed by Liang (1995) due to possible measurement errors caused by heterogeneous characteristics of inputs, for example, skilled labour, unskilled labour and manager etc. Using the translog

[24] The original 18 industries were combined into 11 industries in order to be consistent with other statistics. The detailed aggregation of industries is available in Table VI of Okuda (1994, p. 433); for instance, chemicals industry now comprises chemical material, chemical products, petroleum and coal, and rubber products.

index with gross output and four inputs (labour, capital, materials and energy), the average annual TFP growth rates of overall manufacturing turned out to be 0.12% and 1.41% during the periods 1973–82 and 1982–87.[25] Moreover, ten out of 17 industries suffered TFP decline for the years 1973–82 and five experienced negative TFP growth during the period 1982–87.

Unlike most TFP studies, Chuang (1996) applies the regression approach to measure TFP growth for the entire manufacturing sector finding that it increased at an average annual rate of 1.9% between 1975 and 1990. After incorporating trade-induced learning, Chuang further suggests that over 40% of manufacturing output growth in Taiwan was attributed to a 'trade-induced learning' effect which is treated as TFP growth in his study. Yet, detailed TFP growth estimates for individual manufacturing industries are unavailable.

Extending Liang's (1995) study, Liang and Jorgensen (1999) compare TFP growth estimates for Taiwan's manufacturing industries on the basis of two different output measurements, gross output and value added. The average annual TFP growth rates computed from value added for overall manufacturing were, respectively, 2.33%, 2.72% and 2.46% over the periods 1961–82, 1982–93, 1961–93. Correspondingly, average annual TFP growth rates calculated from gross output appeared to be much lower and turned out to be 0.2%, 0.55% and 0.32%, respectively. Further examination and interpretation regarding these two distinctive estimates are unfortunately unavailable from their study.

Hu and Chan (1999) apply growth accounting in conjunction with human capital to estimate TFP progress in 15 Taiwan manufacturing industries. On average, overall manufacturing TFP grew at 3.1% per annum (employees as labour input) or 3.4% (hours worked as labour input) over the period 1979–96.[26] Because quality improvement embodied in capital and labour inputs have not been adjusted, their TFP growth estimates apparently overstate the extent of actual TFP growth. With regard to individual industries, the chemical industry, including chemical material, products, rubber and plastics, enjoyed

[25] The results of manufacturing industries are only available until 1987 in Table 3 of Liang (1995, pp. 22-23).
[26] Hu and Chan (1999) also report that human capital adjusted TFP growth rates of the manufacturing sector were correspondingly as high as 5.5% and 6.0% during the sample period.

the highest average annual TFP growth rate of 7.1% while precision instruments and other industrial products industry experienced negative 1.3% growth in TFP.

Using a Törnqvist TFP index, an official publication '*The Trends in Multifactor Productivity, Taiwan Area, Republic of China*, 2000' published by the Directorate-General Budget, Accounting and Statistics (DGBAS) provides annual TFP growth estimates as well as TFP levels for the aggregate manufacturing sector and 18 manufacturing industries from 1978 to 1998. Over the period, the average annual TFP growth of the aggregate manufacturing sector was 1.9%. However, the DGBAS (2000) does not allow for imperfect competition; as expected, those official figures unavoidably overestimate the real TFP growth rates for Taiwan's manufacturing industries.

Aw, Chen, and Roberts (2001) apply the multilateral TFP index proposed by Caves *et al.* (1982) and Good *et al.* (1997) and three Industrial and Commercial Census data in 1981, 1986 and 1991 to investigate the Taiwanese firms' TFP differentials.[27] By defining industry productivity as the market-share weighted sum of the firm productivity levels, they subsequently compute TFP growth for the nine manufacturing industries at the 2-digit level. Except the transportation equipment industry, all industries gained TFP growth between 7.8% (clothing) and 36.6% (chemicals) over the period 1981–91. At the manufacturing level, the weighted TFP growth was estimated to be 32.4% during the decade (or 3.2% per annum).

Färe *et al.* (1995) focus on four Taiwanese major industry groupings, comprising essential goods, chemicals, metal machinery and electrical precision. Using the non-parametric DEA (Data Envelopment Analysis) approach, the TFP level of the overall manufacturing sector measured by the Malmquist TFP index progressed at 3.59% annually due completely to technological progress during the period 1978–89. Subsequently, Färe *et al.* (2001) extend their earlier study and calculate Malmquist productivity indexes for 16 of Taiwan's manufacturing industries between 1978 and 1992. They suggest that Taiwan's manufacturing sector has on average enhanced TFP by 2.89% per annum with 2.56% attributed to technological progress and 0.33% to technical efficiency improvement; that is, technological progress largely accounted for TFP growth.

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[27] The details of the variables involved in the estimation are available in Aw *et al.* (2001, pp. 82-84).

A brief summary of the main findings of these TFP studies on the five East Asian manufacturing sectors is presented in Table 2.2

Table 2.2 TFP studies on the manufacturing sector in the five East Asian economies (continued)

Author	Period	Method	TFPG p.a. (%)
Hong Kong			
Kwong, Lau and Lin (2000)	1984–93	growth accounting	–1.53
Imai (2001)	1981–90	growth accounting	5.6
	1991–97		6.0
Japan			
Norsworthy & Malmquist (1983)	1965–73	translog function with gross output	0.91
	1973–78		1.64
Jorgenson *et al.* (1987)	1960–79	translog quantities index	0.83
Morrison (1990a)	1960–81	generalised Leontief cost function	0.987
Prasad (1997)	1971–93	–	2.8
Nakajima *et al.* (1998)	1964–88	index number approach	3.731
Sato (2002)	1979–85	–	2.5
	1985–91	–	2.6
	1991–97	–	2.2
Korea			
Kwon (1986)	1961–80	growth accounting with a cost func.	2.95
Dollar and Sokoloff (1990)	1963–79	growth accounting	6.1
Kang and Kwon (1993)	1963–73	growth accounting with a cost func.	3.43
	1973–83		0.16
Pilat (1995)	1967–87	growth accounting	4.3
Park and Kwon (1995)	1967–89	generalised Leontief cost function	–1.6
Okuda (1997)	1970–93	growth accounting	3.2
Lee, Kim, and Heo (1998)	1967–93	Malmquist productivity index	0.286
Hwang (1998)	1973–93	growth accounting	2.06
		augmented Solow model	2.46
Kim (2000)	1966–88	traditional growth accounting	1.9
		modified growth accounting	0.5
Kwack (2000)	1971–93	growth accounting	3.0
Yuhn and Kwon (2000)	1962–81	growth accounting with a cost func.	1.52
Kim and Han (2001)	1980–94	stochastic frontier approach	7.3
Singapore			
Tsao (1985)	1970–79	growth accounting	0.08
Wong and Gan (1994)	1981–90	growth accounting	1.6
Rao and Lee (1995)	1976–84	growth accounting	–0.4
	1987–94		3.2
Leung (1997)	1983–93	growth accounting	2.8
Mahadevan & Kalirajan (2000)	1976–84	stochastic frontier approach	0.92
	1987–94		–0.52

TFP studies on the manufacturing sector in the five East Asian economies

Taiwan			
Okuda (1994)	1978–91	growth accounting	2.6
Liang (1995)	1973–82	growth accounting	0.12
	1982–87		1.41
Chuang (1996)	1975–90	regression approach	1.9
Liang and Jorgensen (1999)	1961–93	growth accounting	2.46
Hu and Chan (1999)	1979–96	growth accounting	3.1
DGBAS (2000)	1978–98	Törnqvist TFP index	1.9
Aw, Chen, and Roberts (2001)	1981–91	multilateral TFP index	3.24
Färe *et al.* (1995)	1978–89	Malmquist productivity index	3.59
Färe *et al.* (2001)	1978–92	Malmquist productivity index	2.89

2.8 CONCLUSION

As seen from the above TFP reviews, the existing empirical results differ significantly. Even for the same country, TFP growth estimates often vary extensively; for instance, the average annual TFP growth estimates for the entire Korean manufacturing sector ranged from –1.6% in Park and Kwon (1995) to as high as 7.3% in Kim and Han (2001). So, what has contributed to these discrepancies?

- *Different methodologies or specifications*

Taking Taiwan as an example, it is found that the methodologies used vary from study to study including the growth accounting, regression approach, DEA (Malmquist productivity index) and multilateral TFP index etc. Although growth accounting has been prevalently applied in many TFP studies, different specifications of production function may lead to different outcomes; for instance, Hu and Chan (1999) incorporate human capital into the growth account framework and in a series of TFP studies on Korean manufacturing Jene K Kwon insists on taking account of capital utilisation while estimating the growth of capital input.

- *Sources of data sets and sample periods covered*

Not surprisingly, different types and sources of data sets generate various outcomes, for example, the firm-level data in Aw, Chen, and Roberts (2001) and the aggregate data at the industry level in other studies. Besides, the sample periods always vary across studies, which to some extent make it difficult to compare outcomes.

- *Industrial classifications or aggregations*

Interestingly, industrial classifications or aggregations are not always the same even for the same country according to the earlier TFP studies review. In the case of Singapore, there were 27 industries in Bloch and Tang (1999), 28 in Tsao (1985), and Mahadevan and Kalirajan (2000), and 30 in Leung (1997). In the case of Taiwan, the classifications or aggregations were even more diverse. The number of industries examined ranged from 11 to 17 as seen in section 2.7. Occasionally, estimation of TFP growth was carried out for the entire manufacturing sector as a whole rather than for individual industries, e.g., Chuang (1996).

- *Variable constructions and adjustments.*

With regard to the construction and adjustments of variables, quality improvement embodied in labour and capital inputs have frequently been ignored, which may lead to overestimation of the extent of TFP growth. The different choice of 'hours worked' or 'number of employees' as the measure of labour input certainly gives rise to various conclusions. Finally, it is observed that applying gross output as the measure of firm or industry performance rather than value added in some studies will also produce discrepancies.

To examine TFP growth in the five East Asian manufacturing sectors, this study applies the varying coefficients frontier model to avoid the limitations and strict assumptions imposed by the growth accounting and conventional stochastic frontier approach. As growth accounting cannot possibly distinguish the difference between TFP growth and technological progress, following the rationales introduced by Nishimizu and Page (1982) the decomposition approach outlined in Chapter 3 will demonstrate why growth accounting is unrealistic in which technical efficiency improvement can play an important role in the process of enhancing TFP growth and sequentially raise output growth. The detailed specifications of the varying coefficients frontier approach and empirical model are described in Chapter 3.

A uniform data set from the UNIDO database, which covers manufacturing industries at the 3-digit level and has a consistent industrial classification for each country, will facilitate the investigation of the sources of output growth in the East Asian manufacturing sectors.[28] More importantly, the adjustment of quality improvement embodied in labour and capital inputs and construction of variables will homogeneously be undertaken. Thus, the comparison of TFP growth for manufacturing industries can be mostly fulfilled. Unfortunately, the UNIDO database does not hold the data of manufacturing GFCF for Taiwan; data sources for Taiwan are obtained from the official publications by the DGBAS, Taiwan, the Republic of China. The details of data sources are presented in Chapter 3.

[28] There are some industrial aggregations in the cases of Hong Kong, Singapore and Taiwan due to missing data and the change of industrial classification.

Chapter 3

3 METHODOLOGIES AND DATA SOURCES

This chapter discusses methodologies, data sources, and variable constructions used in this study. Section 3.1 briefly reviews some popular methodologies of measuring TFP growth including the conventional stochastic frontier, and meta-production function. The review is followed by the discussion of a recent methodology of the varying coefficients frontier model. A major limitation of most of the earlier studies on TFP growth, particularly growth accounting based studies, is the synonymous use of TFP growth with technological progress. This is problematic. The empirical literature indicates that TFP growth can be obtained not only through technological progress but also by improving the technical efficiency with which the chosen technology is applied. Hence, section 3.2 demonstrates the decomposition analysis in which output growth can be decomposed into input growth, technical efficiency change and technological progress; that is, TFP growth combines the effects of technical efficiency change and technological progress. More importantly, the decomposition of TFP growth is particularly helpful from the policy perspective. Section 3.3 describes the model and associated tests. Section 3.4 discusses data sources. Section 3.5 details the variables constructions as well as the selection of deflators. The UNIDO Industrial Statistics and industry coverage is presented in the Appendix.

3.1 THEORIES AND METHODOLOGIES

Analysis of the sources of growth in East Asia has long been recognised to be an important issue. However, there is not yet consensus on the role of TFP growth in the East Asian economies. Given that many empirical TFP results importantly depend on the choice of methods, this section reviews some of the popular measures of TFP growth used in the literature. After a general discussion of TFP measures, the meta-production function approach proposed by Kim and Lau (1994) is reviewed in section 3.1.1. Section 3.1.2 discusses the stochastic frontier and three other deterministic approaches. Finally, a recent methodology of the varying coefficients frontier approach used in this study is discussed in section 3.1.3.

3.1.1 General Review on TFP Methodologies

Using time series, the conventional factor share growth accounting approach in the absolute form (TFP growth) was initially proposed by Tinbergen (1942) and Solow (1957). Later, Jorgenson and his associates introduced the use of Divisia and translog indices to growth accounting, reflecting the necessity of dividing factor inputs into a number of categories. The other category of time-series approach in the relative form (TFP levels) was initiated by Jorgenson and Nishimizu (1978) and applied to international TFP comparison. For other applications of this approach, see Christensen, Cummings and Jorgenson (1980, 1981), Caves, Christensen and Diewert (1982a), Wolff (1991) and Dollar and Wolff (1994). Also, Nadiri and Prucha (1999) demonstrate a comparison between a dynamic factor demand model and conventional Divisia TFP index.[29]

Although conventional factor share growth accounting has thus far received more attention in the literature, criticisms against it have been well documented in Chen (1997), Felipe (1999), Nelson and Pack (1999), to mention a few.[30] Discussion of the growth accounting approach with a detailed breakdown of factor inputs suggested by Jorgenson *et al.* (1987) is succinctly described in the Appendix 3.6.2. The second approach of growth accounting involves estimating the factor shares through the production function using ordinary least square (OLS) procedures. Some recent examples of this kind of research are Hall and Jones (1996) and Islam (1995). The detailed specifications, advantages and weaknesses regarding this approach are available in Islam (1999).

Kim and Lau (1994) employ the meta-production function approach to measure productivity growth in the four East Asian economies in comparison with the five developed OECD countries specifying that all countries have the same meta-production

[29] They argue that if the underlying assumptions do not hold, e.g., constant returns to scale, then conventional growth accounting approach will, in general, yield biased estimates of technical change. However, the econometric approach based on general dynamic factor demand models allows for a careful testing of various features of a postulated model.

[30] Moreover, Barro (1999) extends the applications of growth accounting to various scenarios including the most recent endogenous growth model. Hulten (2000) clarifies the misconception against growth accounting approach and further explains the associated issues surrounding the approach.

function.[31] It is assumed that the efficiency-equivalent quantities of output and inputs, Y_{it}^{*} and X_{ijt}^{*}, are associated with time-varying, country- and commodity-specific augmentation factors $A_{ij}(t)$'s, $i = 1, \ldots, n$, $j = 0, \ldots, m$, the production function can be expressed as

$$Y_{it} = A_{i0}(t)^{-1} F(X_{i1t}^{*}, \ldots, X_{imt}^{*}), \; i = 1, \ldots, n, \tag{3.1}$$

where $F(\cdot)$ is a translog production function and $Y_{it}^{*} = A_{i0}(t)Y_{it}$, $X_{ijt}^{*} = A_{ij}(t)X_{ijt}$, $j = 1, \ldots, m$. Further assumptions include that the commodity-augmentation factors are assumed to have constant geometric form with respect to time, $Y_{it}^{*} = A_{i0}(1 + c_{i0})^{t} Y_{it}$, and $X_{ijt}^{*} = A_{ij}(1 + c_{ij})^{t} X_{ijt}$, where augmentation level parameters (A_{i0}'s and A_{ij}'s) and augmentation rate parameters (c_{i0}'s and c_{ij}'s) are constants and subject to a normalisation. Besides, they add up to another equation that considers the payment of labour input to total output. The detailed discussion of the estimation process can be found in Kim and Lau (1994, p. 244).

The comments by Rao and Lee (1995, p.85) on the results produced by the meta-production function approach suggest there is a difficulty in interpreting the augmentation in output and inputs in real life. Next, it is unclear whether Kim and Lau's results stay robust if the frontier technology of the numeraire country is changed. Further, although the hypothesis of the existence of a unique meta-production cannot be rejected for the sample of four NICs and the combined sample of NICs and G-5, an increase in the number of sample countries will eventually alter estimated values of the relevant coefficients. Thus, what is the final meta-production function and how it can be interpreted empirically? Finally, the estimation method using instrumental variables has certain obvious limitations.

Besides the above variants of growth accounting, another major approach to TFP growth is the 'production frontier approach', which can be subdivided into two categories. The first category is the non-parametric approach – the Malmquist productivity index,

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[31] The former consists of Hong Kong, South Korea, Singapore and Taiwan and the latter of France, West Germany, Japan, UK, and the United Sates.

which is widely used in empirical studies. Under this framework, TFP growth can be decomposed into several components such as technical progress, technical efficiency change and scale efficiency change. For instance, Caves, Christensen and Diewert (1982b) apply the Malmquist productivity index to compare relative productivity among countries.[32] Nevertheless, one of the major drawbacks of this approach is that empirical results are generally sensitive to outliers, which may subsequently lead to biased outcomes. For a general overview of the Malmquist productivity index, see Färe, Grosskopf and Lovell (1994) and Färe *et al.* (1994). The second category is a parametric frontier approach. Though a number of econometric approaches have been suggested in the literature to estimate the production frontier, which shows the maximum possible output, the stochastic frontier approach popularised by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977) has attracted more attention.

3.1.2 Stochastic Frontier Approach

Several survey articles such as Førsund, Lovell and Schmidt (1980), Bauer (1990), Coelli (1995), and Kalirajan and Shand (1999) have provided indispensable reviews on the stochastic production frontier. The detailed specifications and estimations are described in those surveys; hence, this study will briefly stress some of the key aspects only.

One of the features highlighting the popularity of the stochastic frontier is that it considers the possibility of a firm's performance being affected by some uncontrollable factors such as bad weather as well as controllable factors such as inefficiency. More specifically, the symmetric component specified in the stochastic frontier approach allows for variation of the frontier across firms and captures measurement error, statistical noise and varying shocks outside the firms' control. In addition, the one-sided component captures the effects of inefficiency relative to the stochastic frontier (Aigner *et al.*, 1977). Therefore, the stochastic frontier function is specified as

$$y = f(x)\exp(v-u), \qquad (3.2)$$

[32] They also show that the Tornqvist and Malmquist indices yield the same result if the two underlying technologies have translog forms.

where the stochastic production frontier is $y = f(x)\exp(v)$ and v is assumed to be symmetric to capture the varying effects of measurement error and exogenous shocks which cause the placement of the deterministic kernel $f(x)$ to vary across firms. Technical inefficiency relative to the stochastic production frontier is captured by the one-sided error component $\exp(-u)$, $u \geq 0$. For other details of estimation, see Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977).

Bauer (1990) argues that there has been substantial progress towards more flexible functional forms and more varieties of systems of equations, such as cost, profit and distance functions. Even firm-specific estimates of inefficiency can be obtained after imposing specific distributional assumptions. Coelli (1995) concludes that the proper selection of methods, either the stochastic frontier or data envelopment analysis (DEA), largely depends on the application being considered. In the case of agricultural studies, the stochastic frontier approach is generally preferred.

Nevertheless, the scenario of the stochastic frontier approach remains far from realistic because various constraints may affect the performance of firms, such as style of management, experience of firms, scale or size of firms, which more or less contribute to firm's actual output. For instance, a firm located in a convenient location with good management and more experience in production will always outperform those with poor management and little experience. Put differently, firms or industries may not fully apply the best practice production technology due to various reasons, such as firms' experience, ability of employees. Moreover, the ability to coordinate labour and capital are likely to differ across firms. All these factors will generate an impact on the coefficients of factor inputs (capital and labour); that is, there will be a significant variation in the estimated coefficients of capital and labour inputs implying a non-neutral shift in production frontier.

Empirically, Kim and Han (2001) find the evidence of non-neutral technological progress indicating varying coefficients of capital and labour for the manufacturing firms listed in the Korean Stock Exchange, presumably large firms, over the period 1980–94. As opposed to the constant marginal rates of technical substitution (MRTS) of the conventional stochastic frontier, Huang and Liu (1994) argue that the MRTS at any input combination should not be constant by all means because firms may have learned more knowledge and experience with respect to one input productivity than another.[33] Hence, they propose the non-neutral stochastic frontier model in which the production frontier is a non-neutral shift from the average production function. Therefore, to avoid the drawbacks of the conventional stochastic frontier this study applies the varying coefficients frontier model to capture firms' different applications of the best practice technology. Kalirajan and Shand (1999) detail the strengths and weaknesses of the following four approaches to measuring productivity: DEA, stochastic frontier, stochastic varying coefficients frontier, and Bayesian. In particular, the stochastic varying coefficients frontier approach stands out as superior to others because it may be considered to have some advantages of using both the DEA and stochastic frontier approach and be viewed as a stochastic counterpart of DEA. The details of the modelling of the varying coefficients frontier will be illustrated next and the empirical model presented in section 3.2.

Recently, Kumbhakar, Heshmati and Hjalmarsson (1999) have empirically compared various approaches to measuring TFP growth. They employ six variants of the time trend and general index models to derive the TFP growth for the Swedish cement industry. The three extensions of the time trend model include the standard translog model, firm-specific technical change translog model of Cornwell, Schmidt and Sickles (1990), and the generalised translog model of Stevenson (1980). The other three generalised index models are composed of Baltagi-Griffin (1988) and Lee-Schmidt (1993) models. Despite some consensus among the six models on the degree of TFP growth, the model suggested by Stevenson (1980) is preferred according to the statistical tests and empirical results.

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[33] With the assumption that the production technology of firms can be represented by a Cobb-Douglas function, $Y = AL^{\alpha}K^{\beta}$, i.e., $\ln Y = \ln A + \alpha \ln L + \beta \ln K$, the calculation of marginal rates of technology substitution (MRTS) between labour and capital yields: $MRTS_{LK} = -dK/dL = -\alpha K/\beta L$. If the coefficients, α and β, are constant, then, MRTS is also constant, which implies a shift in production frontier is neutral. Graphically, it represents an upward shift in production frontier or a change in intercept term but no variations in slopes, i.e., estimated response coefficients. However, if the MRTS varies due to changes in coefficients (α and β), it is referred to as a non-neutral shift in production frontier. Conventionally, the stochastic frontier approach adopts the neutral shift in production frontier, which will occur, only if the MRTS between inputs remains constant. In applying the varying coefficients frontier model, the restrictive assumption of constant MRTS can be relaxed and the shift in production frontier turns out to be non-neutral. Compared with growth accounting, one of the advantages of the varying coefficients frontier approach is that it does not require strong assumptions, such as perfect competition, constant returns to scale.

Nevertheless, they concluded that more examinations and simulations on various models are required to gain a better understanding of TFP measures.

3.1.3 Varying Coefficients Frontier Model

In contrast to the stochastic frontier approach, the varying coefficients frontier model avoids the hypothesis of homogeneous behaviour in the method of application of inputs across firms. In practice, actual output across firms may differ due to management styles, organisational or institutional factors, and qualities of labour forces. Empirically, given the same levels of inputs, data often show that different levels of actual output are obtained because firms have various methods of utilising the best available production technology. In order to account for such differences, it is vital to take account of the heterogeneity of firms and estimate variations in both intercepts and slope coefficients across firms and over time for the same firm. For a recent application of the varying coefficient frontier model to measuring the TFP growth, see Kalirajan *et al.* (1996) in which they have examined the impact of Chinese agricultural reforms on the TFP growth.

Following Kalirajan and Obwona (1994), it is assumed the production technology of the East Asian manufacturing industries can be represented by the Cobb-Douglas production function,

$$\ln Y_i = \beta_{0i} + \sum_{m=1}^{M} \beta_{mi} \ln X_{mi}, \; i = 1, \ldots, N, \tag{3.3}$$

where Y_i is the output level of the ith firm, X_{mi} is the level of the mth input used by the ith firm, β_{0i} is the varying intercept term, and β_{mi} is the varying response coefficients of application of the mth input by the ith firm. Equation (3.3) indicates that the estimated response coefficients are unique to each individual firm. Put differently, the response production coefficients vary from firm to firm according to firm-specific characteristics.

Nevertheless, the estimation of equation (3.3) cannot be carried out without further assumptions imposed on the varying coefficients because the number of intercepts and coefficients ($MN + N$) to be estimated exceeds the number of observations (N). To solve the difficulty, the individual varying coefficients are assumed to vary from the mean coefficients, this is,

$$\beta_{mi} = \overline{\beta}_m + u_{mi},\ m = 1,\ldots,M \tag{3.4}$$

where $E(\beta_{mi}) = \overline{\beta}_m$, $E(u_{mi}) = 0$, and $E(u_{mi}) = \sigma_{umm}$ for $i = m$ and 0 otherwise; the varying intercept terms refer to $\beta_{0i} = \overline{\beta}_0 + u_{0i}$. With the additional assumptions, equations (3.3) and (3.4) can be rewritten as

$$\ln Y_i = \overline{\beta}_0 + \sum_{m=1}^{M} \overline{\beta}_m \ln X_{mi} + v_i, \tag{3.5}$$

where $v_i = u_{0i} + \sum_{m=1}^{M} u_{mi} \ln X_{mi}$, $E(v_i) = 0$ for all i, $Cov(v_i, v_j) = 0$, for $i \neq j$ and $Var(v_i) = \sigma_{u00} + \sum_{m=1}^{M} \sigma_{umm} \ln(X_{mi})^2$, $m = 1,\ldots,M$. In fact, this model is a special case of Swamy (1970) and identical to Hildreth and Houck's model (1968). For a general specification of the varying coefficient frontier model in terms of panel data, Swamy (1970), Hsiao (1975) and Kalirajan and Shand (1999, pp. 164–66) provide more details on this debate.

To find the estimates of $\overline{\beta}$, ordinary least squares (OLS) gives unbiased but inefficient estimator. If $Var(v_i)$ were known, the best linear unbiased estimator (BLUE) could be derived by generalised least squares (GLS). Following Hildreth and Houck's (1968) procedure, the mean response coefficients $\overline{\beta}$'s can be estimated under some specific assumptions of $Var(v_i)$. As for the individual response coefficients β_{mi}'s, Griffiths (1972) presents the actual firm-specific and input-specific response coefficient estimator for the ith observation. Drawing heavily on Kalirajan and Obwona (1994), the implications of equation (3.3) are two.

First, technical efficiency is achieved by adopting the best available techniques which involve the efficient use of inputs. Therefore, the sources of technical efficiency stem from: the efficient use of each input which contributes individually to technical efficiency and any other firm-specific intrinsic characteristics which are not explicitly included may produce a combined contribution over and above the individual contributions. The former can be measured by the magnitudes of varying slope coefficients β_{mi}'s and the latter can be obtained by the varying intercept term.

Second, the highest magnitude of each response coefficient and the intercept constitute the production coefficients of the potential production function. These production frontier coefficients, β^*'s, are chosen in such a way to reflect the condition that they represent the production responses of following 'best practice' techniques. Assume β^*_m is the highest response coefficient of the mth input for all firms, i.e., $\beta^*_m = \max_i\{\beta_{mi}\}$, $m = 0,\ldots,M$ and $i = 1,\ldots,N$. Then, the potential frontier output for each firm can be expressed by

$$\ln Y_i^* = \beta_0^* + \sum_{m=1}^{M} \beta_m^* \ln X_{mi}\ ,\ i = 1,\ldots,N. \tag{3.6}$$

Moreover, the characteristics of the frontier coefficients deserve some explanation. First, it is sensible to assume that firms will not utilise all of the inputs efficiently. Despite 'best practice' technology being available to all firms, not all will apply the same method to produce their output due to firm-specific characteristics. Consequently, technical efficiency will vary from firm to firm and the frontier coefficients (maximum coefficients of each input) may not come from any single firm. That is to say, the frontier coefficients $\beta_1^*, \beta_2^*, \ldots \beta_M^*$ may come from different firms. For example, β_1^* is from the 3rd firm and β_2^* the 10th firm and so on, which implies the 3rd firm applies its first input (say, labour) most efficiently and the 10th firm use its second input (say, capital) more efficiently than any of the other firms. Second, the possibility that all frontier coefficients may be selected from a single firm cannot be completely ruled out. It is often observed that a firm which uses some inputs efficiently is likely to use all inputs efficiently.

According to the definition of technical efficiency by Farell (1957), the ith firm technical efficiency (TE_i) can be estimated by the ratio of the actual output to the potential output, namely,

$$TE_i = \frac{Y_i}{\exp(\ln Y_i^*)} \tag{3.7}$$

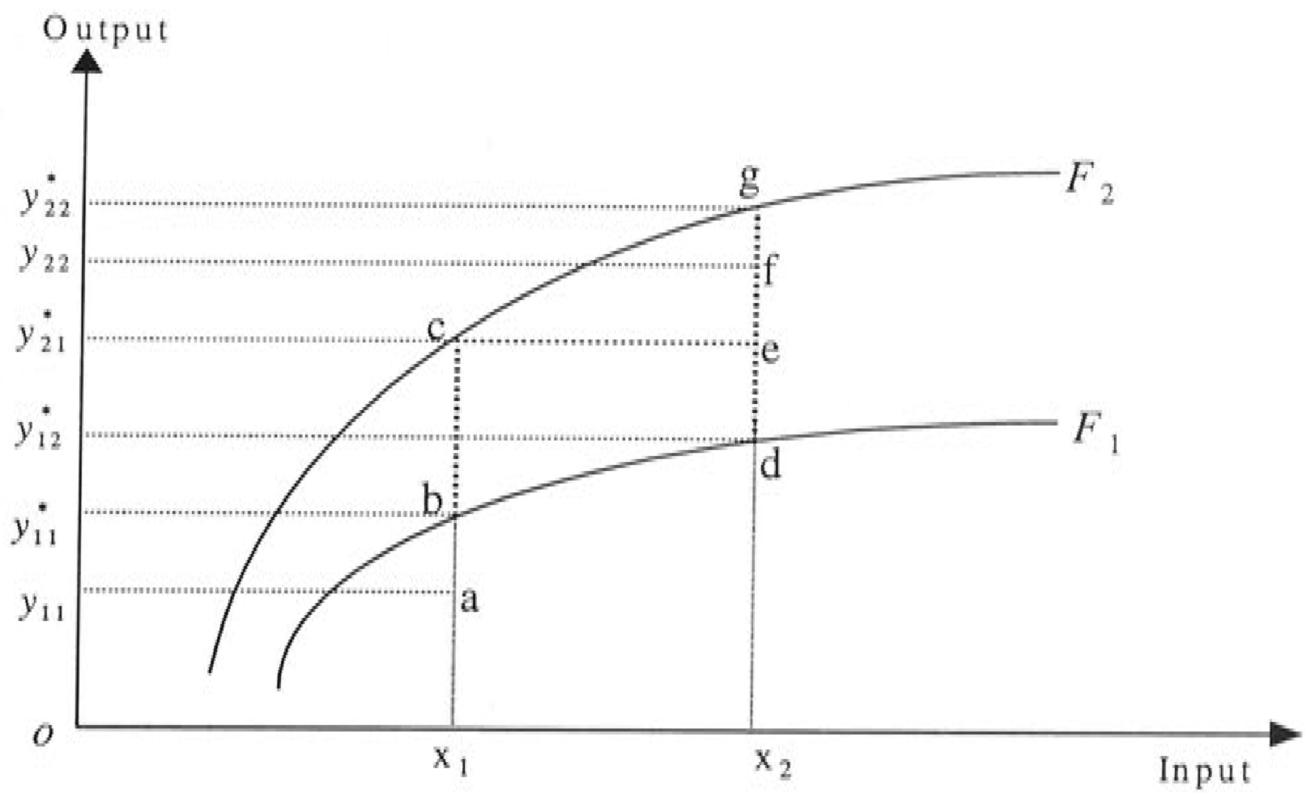
where the numerator (Y_i) denotes the actual output of the ith firm under the best available technology and a given set of inputs and the denominator ($\exp(\ln Y_i^*)$) refers to the estimated potential output of the ith firm, which is the maximum potential output calculated from equation (3.6) if the technology can always be applied efficiently by the firm. An ample application of the varying coefficients frontier model can be found in the literature, such as an examination of the demand for the liquid assets in the U.S. by Feige and Swamy (1974), technical efficiency by Kalirajan and Obwona (1994), production capacity realisation by Kalirajan and Salim (1997). A survey article by Swamy and Tavlas (1995) provides the development of the varying coefficients frontier model with respect to empirical applications and theoretical background.

3.2 A Decomposition Analysis

Discussion on the sources of output growth has been critical in the literature since Abramovitz (1956), Swan (1956), Solow (1957), and Denison (1962). The objective of the debate is to identify the relative contributions of factor inputs and technological progress towards output growth. However, the conventional growth accounting assumption that firms are operating on the production frontier without inefficiency obviously contradicts what is generally observed in practice, namely, firms operating below the production frontier. Firms do not always operate on the production frontier because actual output is often subject to a number of unexpected constraints including uncontrollable and controllable factors. The former comprise bad weather, input supply breakdowns, sudden blackouts or natural disasters etc. and the latter include poor management or inefficiency (Aigner *et al.*, 1977, Meeusen and van den Broeck, 1977). The difference between actual output and frontier output is defined as technical inefficiency (Farell, 1957).

As technical efficiency plays a role central to firm's actual output, Nishimizu and Page (1982) first incorporate the concept of technical efficiency into the TFP growth framework. They follow the non-parametric approach proposed by Aigner and Chu (1968) and decompose output growth into input growth, technological progress and technical efficiency change. As a consequence, TFP growth should be interpreted as the combination of technical efficiency change and technological progress as demonstrated in Figure 3.1. Mahadevan and Kalirajan (1999) also emphasise the importance of the decomposition of TFP growth because TFP growth derived from growth accounting cannot be used synonymously with technological progress.

Figure 3.1 The decomposition of output growth with technical inefficiency



Once the decomposition is made, what has contributed more to the TFP growth in East Asian manufacturing industries can be further examined. In other words, a large technical efficiency improvement stemming from a learning-by-doing effect can increase TFP growth substantially even without much technological progress. Without identifying the real factors behind TFP growth, economic policy will not effectively enhance TFP growth in the region.

In Figure 3.1, F_1 and F_2 refer to the potential production frontiers at periods, T_1 and T_2, i.e., the efficient production technologies, from which maximum potential output is estimated from equation (3.5). The x_1 and x_2 (in logarithms) are the levels of inputs and y_{ij} (in logarithm) is the output level, where i denotes technology (or production frontier) and j represents the level of inputs. Finally, the asterisk (*) denotes that firms efficiently operate on the production frontier. For example, y^*_{11}, which is technically efficient, represents a firm achieving the frontier output by using the technology F_1 with the level of input x_1. If there is an innovation in production technology as a result of innovation, R&D or technology diffusion, technological progress occurs. Then, the potential production frontier shifts from F_1 to F_2 demonstrated by ($y^*_{21} - y^*_{11}$), which means the additional output ($y^*_{21} - y^*_{11}$) is achieved by employing the advanced production technology (F_2) without raising input. In the context of this study, the distance between the two production frontiers ($y^*_{21} - y^*_{11}$) measures technological progress evaluated at x_1.

In practice, firm's output usually appears below production frontiers as shown in Figure 3.1, y_{11} and y_{22}, so that the gap between y_{11} and y^*_{11} reveals the extent of technical inefficiency as described in Farell (1957). According to Figure 3.1, the decomposition of output growth ($y_{22} - y_{11}$) into input growth, a movement towards production frontier and a shift in production frontier can be described as follows.

Output growth $= y_{22} - y_{11} = \overline{ab} + \overline{bc} + \overline{ef} = \overline{ab} + \overline{bc} + (\overline{eg} - \overline{fg}) = (\overline{ab} - \overline{fg}) + \overline{bc} + \overline{eg}$

$= [(y^*_{11} - y_{11}) - (y^*_{22} - y_{22})] + (y^*_{21} - y^*_{11}) + (y^*_{22} - y^*_{21})$

$= (TE_2 - TE_1) + (\Delta TP) + (\Delta Y_x)$

= (*change in technical efficiency*) + (*technological progress at* x_1) + (*input growth from* x_1 *to* x_2 *with production technology* F_2),

where the distance between frontier output (y^*_{11}) and actual output (y_{11}) indicates that firms do not efficiently operate on the production frontier and the loss in output is due to technical inefficiency measured as '*a movement towards or away from production frontier*' (Aigner *et al.*, 1977, Meeusen and van den Broeck, 1977). The gap $(y^*_{21} - y^*_{11})$ implies that using the same amount of input (x_1) but different technologies (F_1 and F_2) the increase in output is attributed to the technological progress measured as '*a shift in production frontier*', i.e., vertically shifting up. The gap between y^*_{22} and y^*_{21} stems from using the same technology (F_2) but with different levels of inputs, x_1 and x_2, namely, output growth due to the increase in inputs. The decomposition framework has shown the important role played by technical efficiency in determining TFP growth.

According to the above illustration, TFP growth is defined as output growth not explained by input growth; that is, TFP growth comprises two components: technical efficiency change and technological progress, i.e., $TFPG = (TE_2 - TE_1) + \Delta TP$. It is worth stressing that the decomposition of TFP growth enables understanding of the status of production technology applied by industries (or firms). In other words, the decomposition analysis facilitates examining whether technological progress is stagnant over time and whether the given production technology has been utilised in an efficient way to completely realise its potential. More importantly, from the policy perspective, these two components are analytically distinct and may have quite different policy implications (Nishimizu and Page, 1982). On the one hand, high rates of technological progress can coexist with deteriorating technical efficiency performance. On the other hand, low rates of technological progress can also coexist with high improvement in technical efficiency. If the technology has not been used to its full potential, introducing new technologies or upgrading the existing technology is wasteful (Kalirajan *et al.*, 1996).

3.3 EMPIRICAL MODEL

Following the varying coefficients frontier model specified in the above section and the underlying assumption that all industries have the same opportunity to access the best available technology, a Cobb-Douglas production technology is assumed for 3-digit manufacturing industries for each economy in East Asia,

$$\ln Y_i = \beta_{0i} + \beta_{1i} \ln L_i + \beta_{2i} \ln K_i,\ i = 1,\ldots,N, \tag{3.8}$$

where Y_i denotes the output level of ith industry measured by value added, L_i is the labour input measured by number of employees adjusted for quality improvement, K_i is capital input measured by the level of capital stock adjusted for quality improvement. The varying intercept is β_{0i} and β_{1i} and β_{2i} are the response coefficients of labour and capital inputs, respectively. All variables are further discussed in section 3.5. Meanwhile, it is assumed that all the varying response coefficients are distributed with a mean and a variance, which facilitates obtaining the estimates of the coefficients, $\beta_{0i} = \overline{\beta}_0 + u_{0i}$ and $\beta_{mi} = \overline{\beta}_m + u_{mi}$, $m = 1,2$. Without much difficulty, as the number of observations are usually larger than the number of estimates. Then, equation (3.8) can be rewritten as

$$\ln Y_i = \overline{\beta}_0 + \overline{\beta}_1 \ln L_i + \overline{\beta}_2 \ln K_i + v_i, \tag{3.9}$$

where $v_i = u_{0i} + u_{1i} \ln L_i + u_{2i} \ln K_i$, $E(v_i) = 0$ for all i, $Cov(v_i, v_j) = 0$ for $i \neq j$, and $Var(v_i) = \sigma_{u00} + \sigma_{u11}(\ln L_i)^2 + \sigma_{u22}(\ln K_i)^2$. The estimation procedure has been detailed in the preceding section. The empirical estimation is carried out using the computer program *TERAN* and the estimation results presented in Chapter 4.

3.3.1 Testing for Heterogeneity of Industries

One of the advantages of the varying coefficients frontier model is that industry-specific characteristics can be taken into account to obtain frontier coefficients when the heterogeneity of industries exists. Whether the given data set is sufficient to reflect such heterogeneity in application of the varying coefficients frontier model can be tested by employing the Breusch-Pagan test. The idea of the Breusch-Pagan test for heteroskedasticity is that if there are some variables $z_1, z_2, \ldots, z_m$ that influence the error variance $Var(\varepsilon_i) = \sigma_i^2$ and if $\sigma_i^2 = f(\alpha_0 + \alpha_1 z_{1i} + \alpha_2 z_{2i} + \cdots + \alpha_m z_{mi})$, then the Breusch-Pagan test is an assessment of the hypothesis:

$$H_0: \alpha_1 = \alpha_2 = \cdots = \alpha_m = 0. \tag{3.10}$$

Additionally, the Breusch-Pagan test does not depend on the functional form. The function $f(\cdot)$ can be any function, such as x^2 or e^x. Assume $\hat{\sigma}^2 = \sum \hat{\varepsilon}^2 / n$ and S = regression sum of squares from a regression of $\hat{u}_i^2$ on $z_1, z_2, \ldots, z_m$. Then, $\lambda = S/2\hat{\sigma}^4$ has a χ^2 distribution with degrees of freedom m.[34] The results of the Breusch-Pagan test for the five East Asian manufacturing sectors are presented in Chapter 4.

3.4 Data Sources

Except for Taiwan, the data for the manufacturing sectors of Hong Kong, Japan, Korea, and Singapore are obtained from the *UNIDO Industrial Statistics Yearbook* compiled by International Economic Data Bank at the Australian National University. It

[34] More details on the Breusch-Pagan LM test can be found in textbooks, such as Maddala, G. S. (1992) *Introduction to Econometrics*, 2[nd], Prentice Hall, and Kennedy, P. (1998) *A Guide to Econometrics*, 4[th] ed, Blackwell.

contains the data of manufacturing industries at the 3-digit level on value added, number of employees, and gross fixed capital formation (GFCF).

Unfortunately, the UNIDO database does not hold the data of manufacturing GFCF for Taiwan. Therefore, the unpublished real and nominal GFCF data are from the Directorate-General Budget, Accounting and Statistics (DGBAS) of Taiwan.[35] In addition, because the industrial classification of the UNIDO differs from that of Taiwan, the UNIDO data on manufacturing value added and number of employees for Taiwan cannot be used together with the manufacturing GFCF data from the DGBAS.[36] Hence, all manufacturing industries data for Taiwan are from the DGBAS. The value added is from "*National Income in Taiwan Area of the Republic of China*" published by DGBAS, the Republic of China. The "*Monthly Bulletin of Manpower Statistics*" contains the number of employees for 22 manufacturing industries since 1979.

The construction of GDP and GFCF deflators can be derived using the nominal and real data of GDP and GFCF, which are available from the publications of national accounts in each country. Alternatively, the deflators of GFCF, GDP, manufacturing value added for the five East Asian manufacturing sectors are from *dX* for Windows 3.0, EconData.

3.5 Data Construction and Adjustment

The variables used in this study comprise manufacturing value added, number of employees and gross fixed capital formation (GFCF). Since manufacturing value added and GFCF are measured at current prices in the UNIDO database, it is necessary to deflate all variables into constant prices. Additionally, the manufacturing value added and GFCF measured in local currencies precludes the adverse influences of exchange rate fluctuations, which may mislead the result of output growth decomposition. More details on these variables are discussed next.

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[35] Gratitude is extended to Mr. Wu-Chi Lai of the DGBAS for providing the unpublished data of manufacturing GFCF for Taiwan. The other possible source regarding the data of GFCF may refer to "*The Trends in Multifactor Productivity, Taiwan Area, the Republic of China*" published by the DGBAS of Taiwan but it contains only 18 manufacturing industries due to aggregation.

[36] It is found that more than half of the classifications of Taiwan's manufacturing industries are not compatible with the UNIDO's International Standard Industrial Classification (ISIC).

3.5.1 Output

Value added is a measure of net output, that is, gross output less those purchased (or intermediate) inputs of goods and services, which have been embodied in the value of the products. Value added avoids double counting since products purchased from other establishments are deducted as input costs. However, the survey data cannot gather all the components needed in calculating 'pure value added'. The value added figure produced is called 'census value added' due to the missing components: purchased services. Census value added is calculated by subtracting the cost of materials, supplies, purchased fuel and electricity used from the value of gross output of manufacturing activity. Hence, the actual output of each manufacturing industry in this study is measured in value added.

3.5.2 Labour

Theoretically, 'hours worked or working hours' is best measured as labour input.[37] However, such data are unavailable from the UNIDO database. Instead, the use of wages and salaries paid to employees (employment) may be a good alternative measure for 'hours worked'.[38] Despite the advantages of using wages and salaries expenditure as the measure of labour input, number of employees is explicitly chosen as the labour input in this study. The major concern comes from whether the marginal product of labour has been enhanced as much as the growth of the real wage in the East Asian manufacturing industries. If the answer is 'negative', then the use of wages and salaries expenditure as the labour input apparently overstates its contribution to output growth. Consider total wages and salaries expenditure in real term is $W = w \cdot L$, where the number of employees and real wage per worker are denoted as L and w, respectively. After logarithmically differentiating total wages and salaries expenditure with respect to time, it can be rewritten as $\dot{W}/W = \dot{L}/L + \dot{w}/w$, indicating that the growth rate of total wages and salaries expenditure equals the growth rate of number of employees plus the growth rate of real wage per worker.

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[37] For example, Jorgenson, Gollop, and Fraumeni (1987) and Young (1992,1995).

[38] First, it can easily reflect the quality improvement in labour input over time because of a growing number of better-educated employees. Second, the idea of marginal product of labour could be captured by wages and salaries expenditure if labour markets were functioning efficiently. To some extent, it might reveal the true contribution of labour input to manufacturing output. Third, because of the existence of part-time and full-time employees, the problem of counting total number of employees or employment can be avoided.

In the case of Singaporean manufacturing industries, the real growth rate of wages and salaries expenditure during the period 1970–97 was 237% and the growth rate of manufacturing employees was 108%; hence, the growth rate of real wage per worker turned out to be 129%. If the marginal product of labour did not increase as much as the real wage per worker, the contribution of wages and salaries expenditure as the measure of the labour input to output growth will be overvalued, which accordingly implies TFP growth being understated.

Why cannot the growth of real wage per worker in the East Asian manufacturing sectors reflect the actual growth of the marginal product of labour? First, one of the comparative advantages in the East Asian manufacturing sectors in the early 1960s and 1970s was cheap labour costs, which attracted massive foreign direct investment to boost these economies. As Huff (1999, p.36) describes, "Control of the labour market enabled the Singaporean government to secure international manufacturing competitiveness through limiting wage rises". Hence, it is understood that in the early days manufacturing workers were mostly underpaid. Second, the rise of the East Asian manufacturing sectors indicates increasing competition with the industrialised economies in many aspects, e.g., electronic products and automobiles. As well, mounting legal protections for workers such as minimum wages legislation and the rising power of trade unions may have caused today's workers to be overpaid. Taking these two factors into account, it is suggested that the growth of real wage per worker would be comparatively higher than that of the marginal product of labour in the East Asian manufacturing industries. Instead of using wages and salaries expenditure, this study adopts the 'number of employees' as the measure of labour input to prevent the contribution of labour input from being overstated.

3.5.3 Capital Stock

The capital stock of each industry is estimated by the conventional perpetual inventory method, $K_t = K_{t-1}(1-\delta) + I_{t-1}$, where K_t and K_{t-1} denote capital stocks at time t and $t-1$, δ is the rate of depreciation, I_{t-1} is real gross investment or, more precisely, gross fixed capital formation (GFCF) carried out at time $t-1$.[39] If the growth rate of GFCF

[39] Gross fixed capital formation is defined as the outlays of producers on durable real assets, such as buildings, motor vehicles, plant and machinery, roads, and improvements to land. In measuring the outlays, sales of similar goods are deducted. Land is excluded from gross fixed capital formation. Included is the

is assumed to be stable over time, the initial capital stock (K_0) can be constructed by the initial GFCF ($GFCF_0$) divided by the sum of the depreciation rate and the average real growth rate of GFCF (g) at the *manufacturing* level in the first ten years of the sample period, i.e., $K_0 = GFCF_0 / (g + \delta)$.[40] Due to lack of data on the detailed components of GFCF, a simple average depreciation rate (δ) of 0.0925 is employed to depreciate capital stock for the East Asian manufacturing sectors with the exception of Singapore. According to Hulten and Wykoff (1981), the depreciation rate of 0.0925 is computed from the four depreciation rates of capital subinputs comprising non-residential (0.029), construction (0.021), transports (0.182), and machinery (0.138), where land is excluded from the construction of capital stock.

For Singapore's manufacturing sector, the choice of the depreciation rate is somewhat sensitive to the empirical results. It is also believed that the depreciation rate of 0.0925 may be too low for the Singaporean manufacturing industries. To favour the outcomes for Singapore, a higher depreciation rate of 0.1768 from Jorgenson's (1990) estimates is adopted to depreciate manufacturing capital stocks. Since the GFCF data are only available at the manufacturing industry level, the simple average depreciation rate of 0.1768 is generated from the four depreciate rates of capital subinputs: non-residential building (0.0361), machinery and equipment (01048), transport equipment (0.2935), and office equipment (0.2729).

In addition to Singapore's manufacturing industries, the higher depreciation rate of 0.1768 is applied to the other four economies for sensitivity tests. For instance, if the higher depreciation rate is applied to Japan's manufacturing sector, the increased TFP growth will be 0.065 over the 1965–1998 period, i.e., 0.2% per annum. For Taiwan's manufacturing sector, it will only be 0.016 during the period 1981–1999, i.e., 0.1% per

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value of construction work done by a firm's own employees. The term 'gross' indicates that consumption of fixed capital has not been deducted from the value of the outlays.

[40] If the average real growth rate of GFCF were chosen from individual manufacturing industries at the 3-digit level, the initial capital stock could become negative in some cases due to the dramatic fluctuations of GFCF in several industries, which is not possible in practice. The average annual real growth rates of GFCF in the initial ten years for the manufacturing sectors of Hong Kong (1976–86), Japan (1963–73), Korea (1970–80), Singapore (1970–80), and Taiwan (1970–80) were 0.050, 0.0857, 0.2011, 0.0840, and 0.1168, respectively. Note that the average annual growth rates of GFCF are geometric *not* logarithmic.

annum. Thus, it is evident that the choice of capital depreciation rate (0.0925) would not bias the outcomes of those four East Asian manufacturing sectors.

3.5.4 Quality Adjustment for Labour and Capital Inputs

In order to capture the quality improvement embodied in labour input due to an increasing number of well-educated employees, this study adopts several labour quality improvement indices from Young (1995). Young estimates the difference between raw labour and quality-adjusted labour input using the technique suggested by Bishop, Fienberg, and Holland (1975) and then suggests that the average annual labour quality adjustment indices for the manufacturing sectors of Hong Kong, Korea, Singapore, and Taiwan were 0.6%, 1.1%, 1.6% and 0.4%, respectively.[41] The quality-adjusted labour input in this study is calculated as number of employees multiplied by one plus the labour quality adjustment index over time. This effectively scales up the number of employees in later years when workers become better educated. However, as far as the labour quality adjustment index is concerned, Chen (1997) argues that the quality improvement of labour input may be over-adjusted in the case of Singapore; hence, the resulting estimates for Singapore's manufacturing industries will be further examined while conducting sensitivity analysis in Chapter 6. If the labour quality improvement index is considered, for instance, the growth rate of the quality-adjusted labour input for Singapore's manufacturing sector over the period 1970–97 will be 150.8% rather than 108% (no adjustment). Because the labour quality adjustment index for Japan is not available in Young (1995), the adjustment index is simply assumed to be 0.5%.

Similarly, the adjustment of quality improvement embodied in capital input (GFCF) is implemented using the capital quality adjustment indices from Young (1995).[42] It is suggested that the average annual capital quality adjustment indices for the manufacturing sectors of Korea, Singapore and Taiwan at the manufacturing level were 0.4%, 0.5% and

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[41] The labour quality adjustment index is the difference between the average annual growth rate of raw labour and weighted labour. The index of 0.6% for Hong Kong was based on the economy level and estimated for the period 1966–91. For Singapore, the estimated index was for the period 1970–90 at the manufacturing level. For Korea (1966–90) and Taiwan (1966–90), the indices were at the manufacturing level. These four indices are adopted from Young (1995, pp. 657–661, Table V–VIII). Despite carrying out the quality adjustments, the empirical results are relatively insensitive to the choices of indices.

[42] Hulten (1992), after adjusting capital input for quality improvement, finds that approximately 20% of the TFP growth could be attributed to embodied technological change in the U.S. manufacturing industry over the period 1943–83.

0.2%, respectively; for Hong Kong, the estimated index was 0.3% at the economy level.[43] Beside, the index for Japan's manufacturing sector is assumed to be 0.4%. The outcome of the adjustments can be easily worked out. The quality adjustment for capital input will raise the growth of capital input; subsequently, it reduces the degree of TFP growth slightly. The magnitude of reduction in TFP growth due to the quality adjustments for labour and capital inputs is therefore interpreted as 'embodied technological change'.

Despite the fulfilment of quality adjustment for capital input, the results of this study remain subject to the extent of the utilisation of capital stock. To minimise the impact, the utilisation of capital stock is implicitly assumed to be constant over the entire period. As long as the capacity utilisation of capital stock is unchanged, the estimates of TFP growth will not be affected in spite of not completely utilising the capital stocks. Nevertheless, if the capital stock utilisation were decreasing over time, the growth of capital input could be overestimated leading to TFP growth being understated.

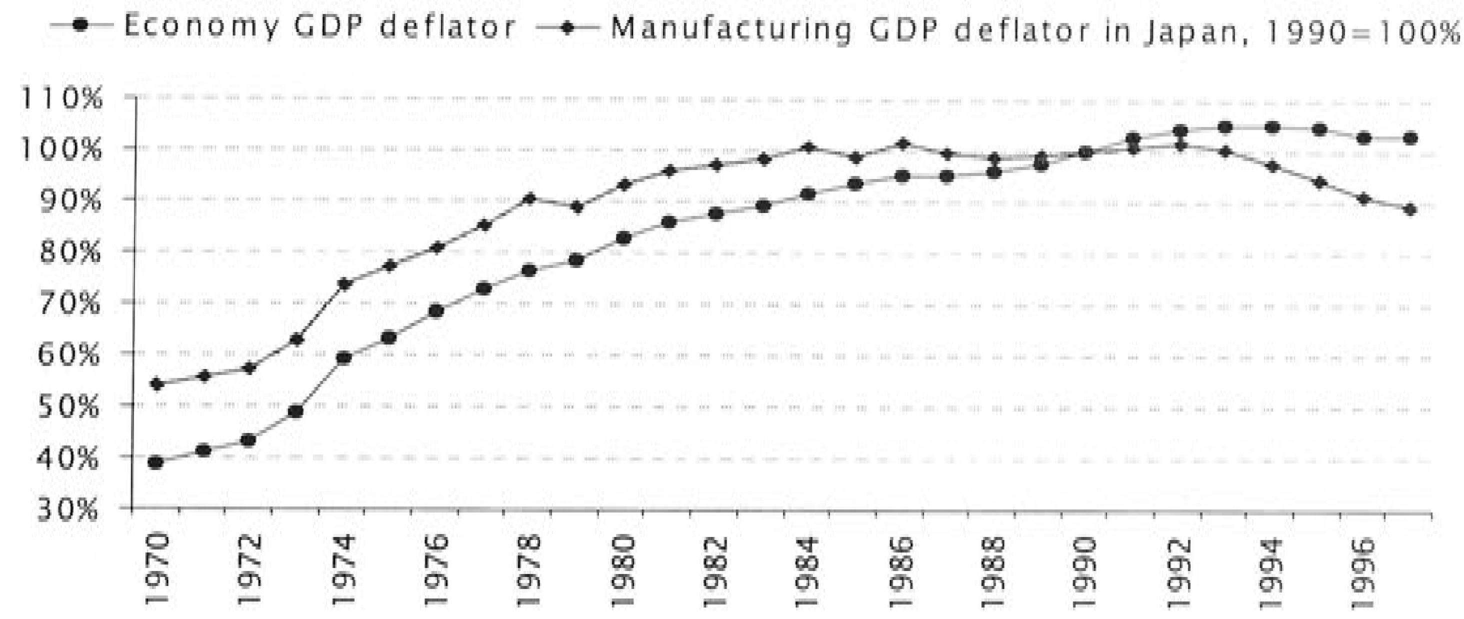
3.5.5 Construction of Deflators

Ideally, it is preferable to use the deflators of *manufacturing* value added and CFGF if both are available. Alternatively, the *economy* GDP and GFCF deflators may be applied to deflate the variables into constant prices. Even so, it has encountered an unexpected hurdle. It might be expected that think the difference between manufacturing value added and economy GDP deflators would be small or negligible. Yet, Figure 3.2 reveals there was a significant distinction between those two deflators in Japan. The economy GDP deflator in 1970 was lower than the manufacturing value added deflator but became higher from 1991. If the economy GDP deflator is used to deflate the nominal manufacturing value added, it will generate a higher real manufacturing value added in 1970 but a lower value added in 1995. Subsequently, the growth rate of manufacturing value added in Japan reduces to 49.5% from 96.6% during the 1970–95 period. Of course, this conspicuously misleads as to the true degree of TFP growth. Hence, the real manufacturing value added at constant 1990 prices is derived using manufacturing value added deflator for all manufacturing sectors except Hong Kong.[44] Due to lack of the

[43] See footnote 41.
[44] In the case of Singapore, the use of the economy GDP deflator to deflate nominal manufacturing value added favours the outcome of output growth and TFP growth but this is certainly deceptive.

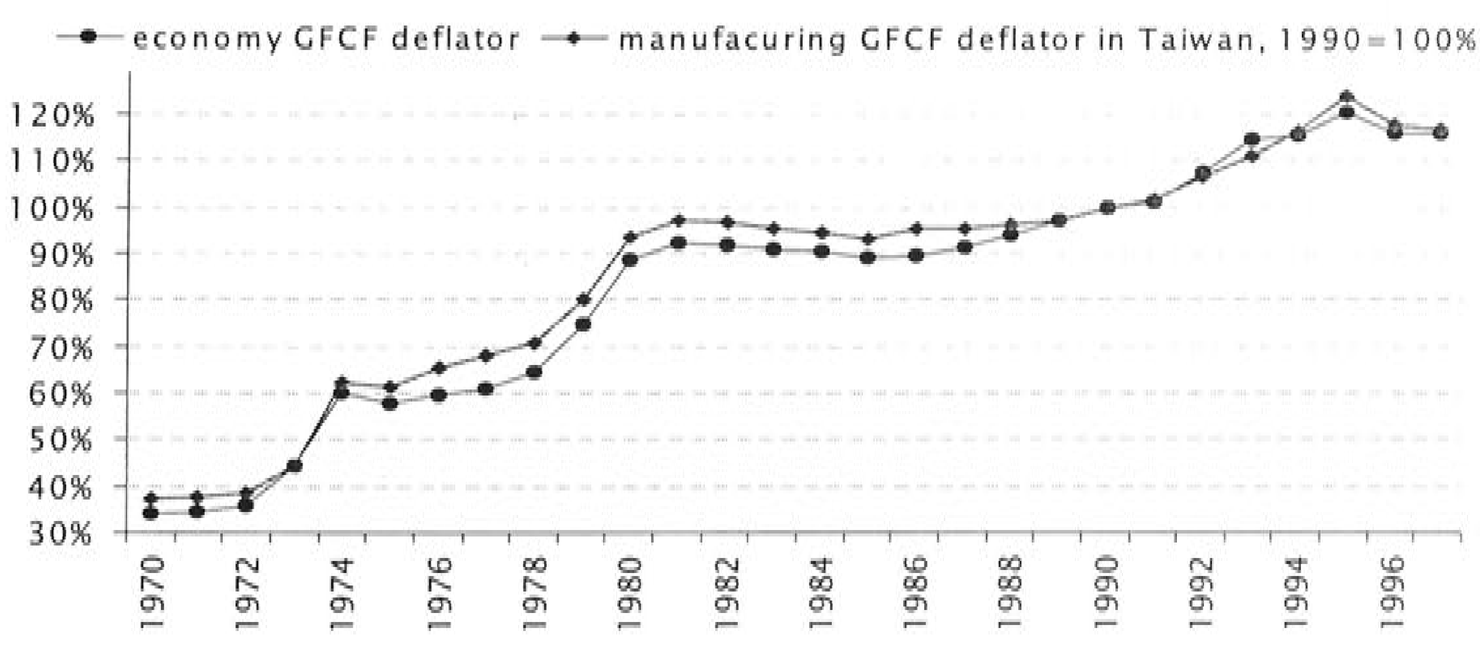
manufacturing value added deflator in Hong Kong, there is no choice but to use the GDP deflator at the economy level.

Figure 3.2 Economy GDP deflator versus manufacturing value added deflator at constant 1990 prices in Japan



Source: Author's calculation based on *dX* for Windows 3.0, EconData: CEIC Database, Japan.

Figure 3.3 Economy GFCF deflator versus manufacturing GFCF deflator at constant 1990 prices in Taiwan



Source: Author's calculation based on *dX* for Windows 3.0, EconData: CEIC Database, Taiwan.

Figure 3.3 shows the economy GFCF and manufacturing GFCF deflators at constant 1990 prices in Taiwan over the period 1970–97. Since the deflator of manufacturing GFCF is only available for Taiwan, the next step is to choose appropriate GFCF deflators for the other four economies. Analogous to Japan, the considerable gap between economy GDP and manufacturing value added deflators exists in Taiwan but as shown in Figure 3.3 the difference between economy GFCF and manufacturing GFCF deflators are negligible. Thus, it is believed that the GFCF deflator at the economy level can be properly substituted as the manufacturing GFCF deflator for Hong Kong, Japan, Korea and Singapore.

The deflators of economy GDP and GFCF for Hong Kong are available from 1973 to 2000. The deflators of manufacturing value added and economy GFCF for Japan and Singapore are available from 1955 to 1999 and from 1960 to 2000, respectively. Two implicit price indexes of fixed capital formation and manufacturing value added for Korea are obtainable in the national accounts from 1970 to 1997. Lastly, the manufacturing value added and GFCF deflators for Taiwan are available from 1962 to 1998 and from 1951 to 1997, respectively.

3.6 APPENDIX

3.6.1 The UNIDO Industrial Statistics and Industry Coverage

The database is based on the International Standard Industrial Classification (ISIC) of All Economic Activities code (three-digit level) at Revision 2, which has the following 29 divisions:

CODE	INDUSTRY
300	Total manufacturing
311	Food products
313	Beverages
314	Tobacco
321	Textiles
322	Wearing apparel, except footwear
323	Leather products
324	Footwear, except rubber or plastic
331	Wood products, except furniture
332	Furniture, except metal
341	Paper and products
342	Printing and publishing
351	Industrial chemicals
352	Other chemicals
353	Petroleum refineries
354	Miscellaneous petroleum and coal products
355	Rubber products
356	Plastic products
361	Pottery, china, earthenware
362	Glass and products
369	Other non-metallic mineral products
371	Iron and steel
372	Non-ferrous metals
381	Fabricated metal products
382	Machinery, except electrical
383	Machinery, electric

384 Transport equipment

385 Professional and scientific equipment

390 Other manufactured products

3.6.2 Growth Accounting Approach

Following Jorgenson, Gollop and Fraumeni (1987), and Young (1995), value added is specified as a translog function of capital and labour inputs:

$$\ln Y = \alpha_0 + \alpha_K \ln K + \alpha_L \ln L + \alpha_T \cdot T + 1/2\,\beta_{KK}(\ln K)^2 + \beta_{KL} \ln K \ln L + \\ \beta_{KT} \ln K \cdot T + 1/2\beta_{LL}(\ln L)^2 + \beta_{LT} \ln L \cdot T + 1/2\,\beta_{TT} \cdot T^2, \tag{3.11}$$

where Y, K, L and T denote value added, capital input, labour input, and time. Under the assumption of constant returns to scale, the parameters satisfy the following conditions:

$$\alpha_K + \alpha_L = 1,\ \beta_{KK} + \beta_{KL} = \beta_{KT} + \beta_{LT} = \beta_{KL} + \beta_{LL} = 0. \tag{3.12}$$

Because the data sets are only available at discrete points of time, say T and $T-1$, the growth rate of output can be expressed as a first difference of $\ln Y(T)$ and $\ln Y(T-1)$:

$$\ln Y(T) - \ln Y(T-1) = \overline{S}_K[\ln K(T) - \ln K(T-1)] + \overline{S}_L[\ln L(T) - \ln L(T-1)] \\ + \overline{TFP}_T, \tag{3.13}$$

where S_K and S_L represent the elasticities of output with respect to capital and labour inputs and $\overline{S}_i = [S_i(T) + S_i(T-1)]/2$, $i = K, L$ and $\overline{TFP}_T = [TFP(T) + TFP(T-1)]/2$. The expression of the average rate of technical change, $\overline{TFP}_T$, is also called the translog index of the rate of total factor productivity growth. The translog index is often referred to as the discrete version of Divisia index or the Törnqvist index. Under the assumption of perfect competition, the share of capital equals its payments to total factor income. Since the sum of capital and labour shares is unity, the capital share can be obtained by one less labour share.

Because aggregate capital and labour inputs consist of a number of components, such as machinery, transport equipment and buildings, aggregate capital and labour inputs are assumed to be the translog function of their components:

$$\ln K = \alpha_1^K \ln K_1 + \alpha_2^K \ln K_2 + \cdots + \alpha_M^K \ln K_M + 1/2\,\beta_{11}^K (\ln K_1)^2 + \beta_{12}^K \ln K_1 \ln K_2 + \cdots + 1/2\,\beta_{MM}^K \ln(K_M)^2, \tag{3.14}$$

$$\ln L = \alpha_1^L \ln L_1 + \alpha_2^L \ln L_2 + \cdots + \alpha_N^L \ln L_N + 1/2\,\beta_{11}^L (\ln L_1)^2 + \beta_{12}^L \ln L_1 \ln L_2 + \cdots + 1/2\,\beta_{NN}^L \ln(L_N)^2. \tag{3.15}$$

Similarly, under the assumption of constant returns to scale, the parameters again satisfy the following conditions:

$$\alpha_1^i + \alpha_2^i + \cdots + \alpha_j^i = 1 \text{ and } \beta_{11}^i + \beta_{12}^i + \cdots + \beta_{jj}^i = 0,\ i = K, L \text{ and } j = M, N. \tag{3.16}$$

Thus, taking first difference of the equations (3.15) and (3.16) provides the growth rates of aggregate capital and labour inputs as weighted averages of the growth rates of their subinputs:

$$\ln K(T) - \ln K(T-1) = \sum \bar{s}_{Km} [\ln K_m(T) - \ln K_m(T-1)], \tag{3.17}$$

$$\ln L(T) - \ln L(T-1) = \sum \bar{s}_{Ln} [\ln L_n(T) - \ln L_n(T-1)], \tag{3.18}$$

where $\bar{s}_{ij} = [s_{ij}(T) + s_{ij}(T-1)]/2$, $i = K, L$, $j = m, n$, $m = 1,2,\ldots M$ and $n = 1,2,\ldots N$. s_{ij} denotes the elasticity of each aggregate input with respect to each of its component subinputs, i.e., the share of each subinput in total payments to its aggregate factor. The expressions for the capital and labour input in equations (3.18) and (3.19) are considered as translog indices of capital and labour inputs. In fact, the indices adjust for quality improvement of aggregate capital and labour inputs. Jorgenson *et al.* (1987) illustrate the importance of disaggregating the inputs by quality levels; for example, labour input is classified by sex, age, education, employment status and occupation of employees. As can be seen from equation (3.19), the growth rate of aggregate labour input is a weighted average of type n multiplied by the associated income share, s_{Ln}. Hence, if the average education level rises over time, the procedure will capture the quality improvement of labour input by assigning a higher weight for category n because of the higher wage, w_n.

Finally, if the TFP growth is interpreted as a shift in an aggregate production, the associated variables have to be measured as flows. Therefore, the flow of labour services is assumed to be proportional to total hours of work and the flow of capital services is proportional to the estimated capital stock, i.e., $L_n(T) = \gamma_{Ln} H_n(T)$ and $K_m(T) = \gamma_{km} C_m(T)$, with

$$\ln K(T) - \ln K(T-1) = \sum \bar{s}_{Km}[\ln C_m(T) - \ln C_m(T-1)], \tag{3.19}$$

$$\ln L(T) - \ln L(T-1) = \sum \bar{s}_{Ln}[\ln H_n(T) - \ln H_n(T-1)], \tag{3.20}$$

where H_n and C_m denote the total hours of work and estimated capital stock, respectively.[45]

[45] The book '*Productivity and U.S. Economic Growth*' by Jorgenson, Gollop and Fraumeni (1987) provides more details on the methodology.

Chapter 4

4 Characteristics of the Five East Asian Manufacturing Sectors and Estimates of Varying Coefficients

Before discussing the outcomes of the test for heteroskedasticity and estimates of varying coefficients, section 4.1 describes the characteristics of the five East Asian manufacturing sectors. The results of the Breusch-Pagan Lagrange Multiplier (LM) test are reported in section 4.2. Section 4.3 shows the estimated frontier, mean coefficients and computer program used in this study. Using the concept of technical efficiency, section 4.4 examines how well manufacturing industries in the East Asian economies utilised labour and capital inputs. Finally, the number of industries covered is thoroughly discussed in the Appendix. The estimated varying coefficients for selected years and the estimation result of the computer program *TERAN* are also included.

4.1 Characteristics of the Five East Asian Manufacturing Sectors

This section presents a number of statistical indicators of individual economies to facilitate understanding of the role of the manufacturing sector in the overall economy. These statistics include average annual real growth rates of manufacturing value added, gross fixed capital formation (GFCF), capital stock, GDP and number of employees. Discussion of inflation rates (or change in GDP deflator), manufacturing share in GDP and the ratio of manufacturing GFCF to manufacturing value added is also provided.[46]

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[46] For consistency, the manufacturing shares in GDP are calculated by using manufacturing GDP from national accounts *not* UNIDO's value added. However, there is no reason why UNIDO's value added cannot be adopted because the difference is insignificant.

It should be noted that the value added and other variables from the UNIDO database are likely to be different from those of national accounts of individual countries.[47] According to the United Nations *International Yearbook of Industrial Statistics* (1999, pp. 7–11), the data of value added from the UNIDO database are in the '*census*' concept and *not* in the 'national accounting' concept in which manufacturing GDP, etc. are measured. The 'census value added' covers only activities of industrial nature, which is defined as the value of census output less the value of census input. However, the 'national accounting value added (or, total value added)' is census value added less the cost of non-industrial services plus the receipts for non-industrial services. Furthermore, the data on census value added as well as on other variables are the results of annual industrial surveys conducted by the national statistical offices in individual countries, which cover only the manufacturing establishments that were registered at those national statistical offices, i.e., those surveys do not cover the 'informal sector nor very small establishments'. In addition, the scope of surveys differs from country to country. Meanwhile, the calculation of growth rates in this study is done by taking a logarithmic difference in two consecutive years and all variables have been deflated at constant 1990 prices. Hence, the figures reported here could be slightly different from those in the official publications.

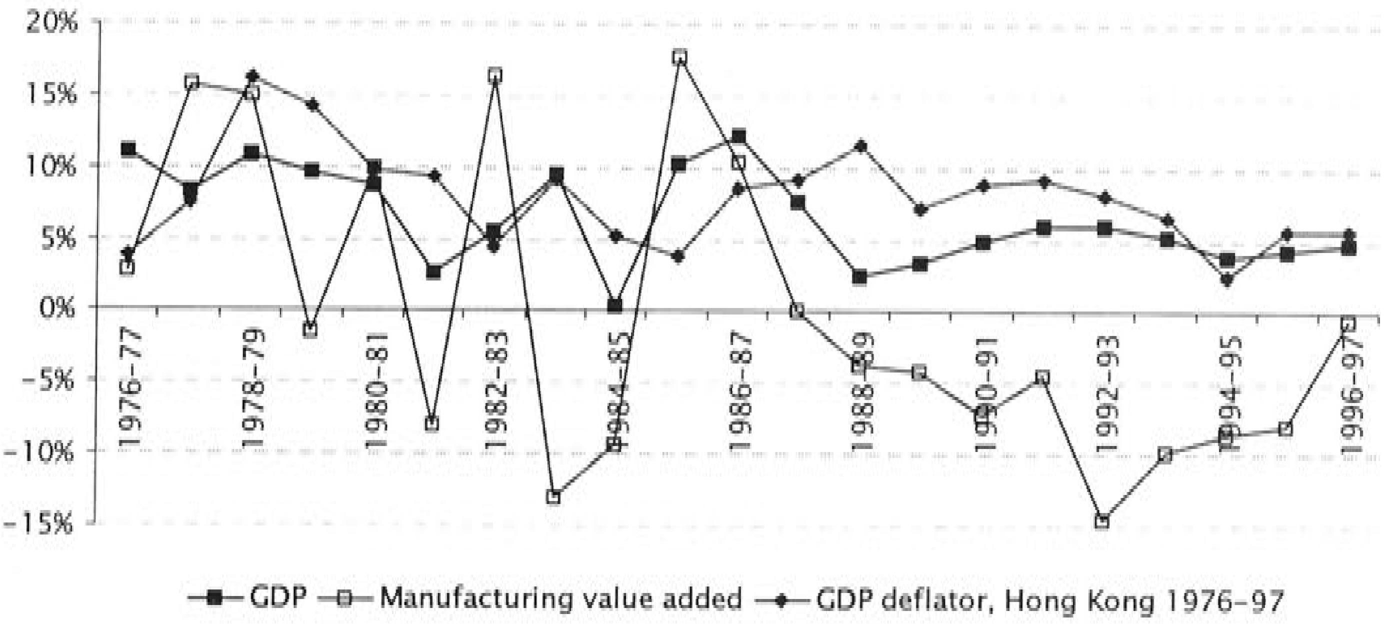
4.1.1 Hong Kong

Figure 4.1 shows the average annual growth rates of GDP, manufacturing value added and GDP deflator in Hong Kong between 1976 and 1997. The growth rate of manufacturing value added became negative since 1989 despite the strong and positive growth rate of the overall economy. Due to the liberalisation policy in China in 1978, the rapid relocation of manufacturing production to nearby mainland China since the mid-1980s largely contributed to the outcome of the negative output growth in the manufacturing sector.[48] Hong Kong's inflation rate generally fluctuated at around 8%, which was higher than Japan, Singapore and Taiwan but lower than Korea.

[47] Mr. Tetsuo Yamada of the Statistics and Information Networks Branch at the UNIDO clarified the puzzle on this matter.
[48] This ongoing structural transformation in Hong Kong's manufacturing industries has created a significant impact on the productivity growth; see Imai (2001), Kwong *et al.* (2000), and Tuan and Ng, (1995).

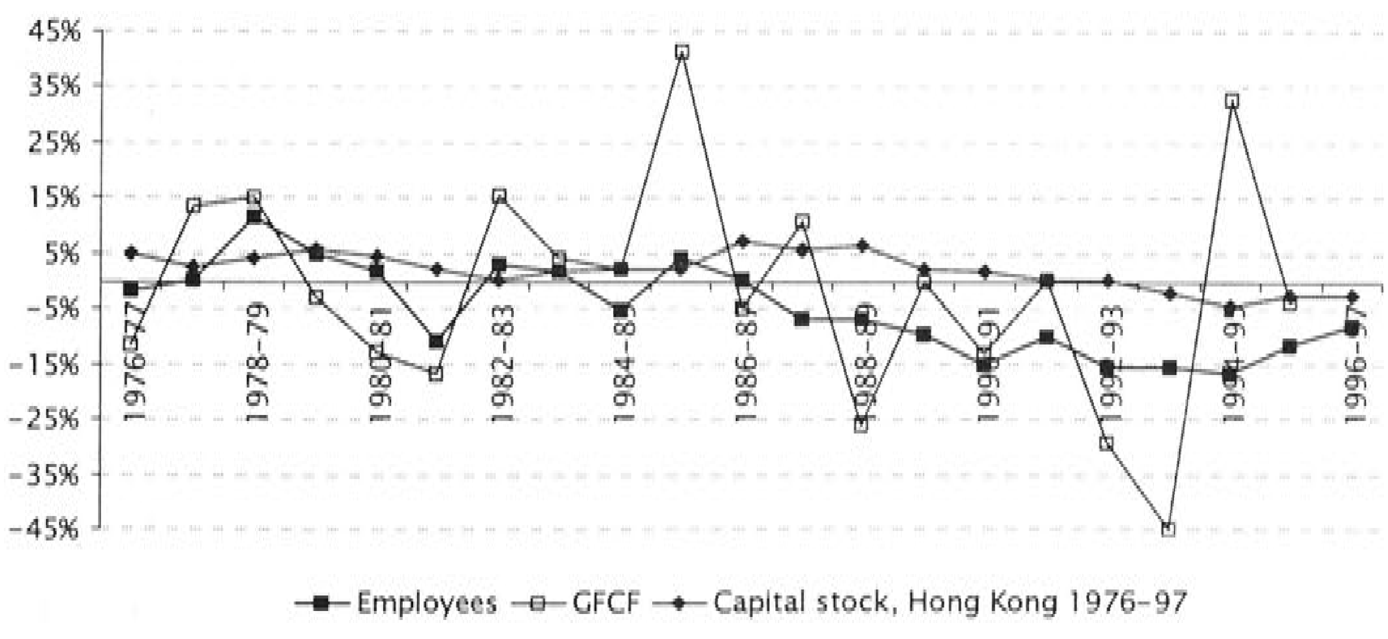
As a result of the manufacturing relocation, the total number of employees in manufacturing industries has been shrinking after 1987 as shown in Figure 4.2. Similarly, the real growth rate of GFCF turned out to be negative since 1989 except for 1995. At the same time, the growth rate of capital stock has been slowing down and it also became negative after 1994.

Figure 4.1 Average annual real growth rates: GDP, manufacturing value added and GDP deflator in Hong Kong



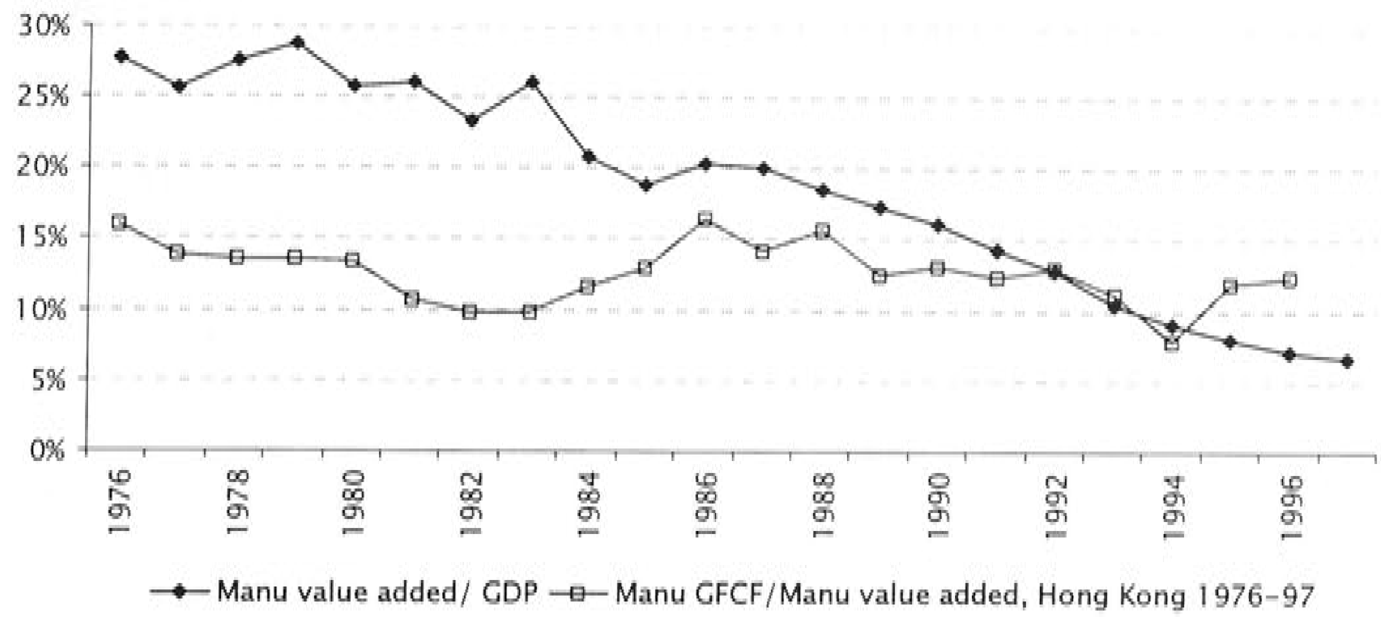
Sources: Author's calculation based on *dX* for Windows 3.0, EconData: CEIC Database, Hong Kong and UNIDO database.

Figure 4.2 Average annual growth rates: number of employees, real GFCF and real capital stock in Hong Kong's manufacturing



Source: As in Figure 4.1.

Figure 4.3 Manufacturing share in GDP and ratio of manufacturing GFCF to manufacturing value added in Hong Kong



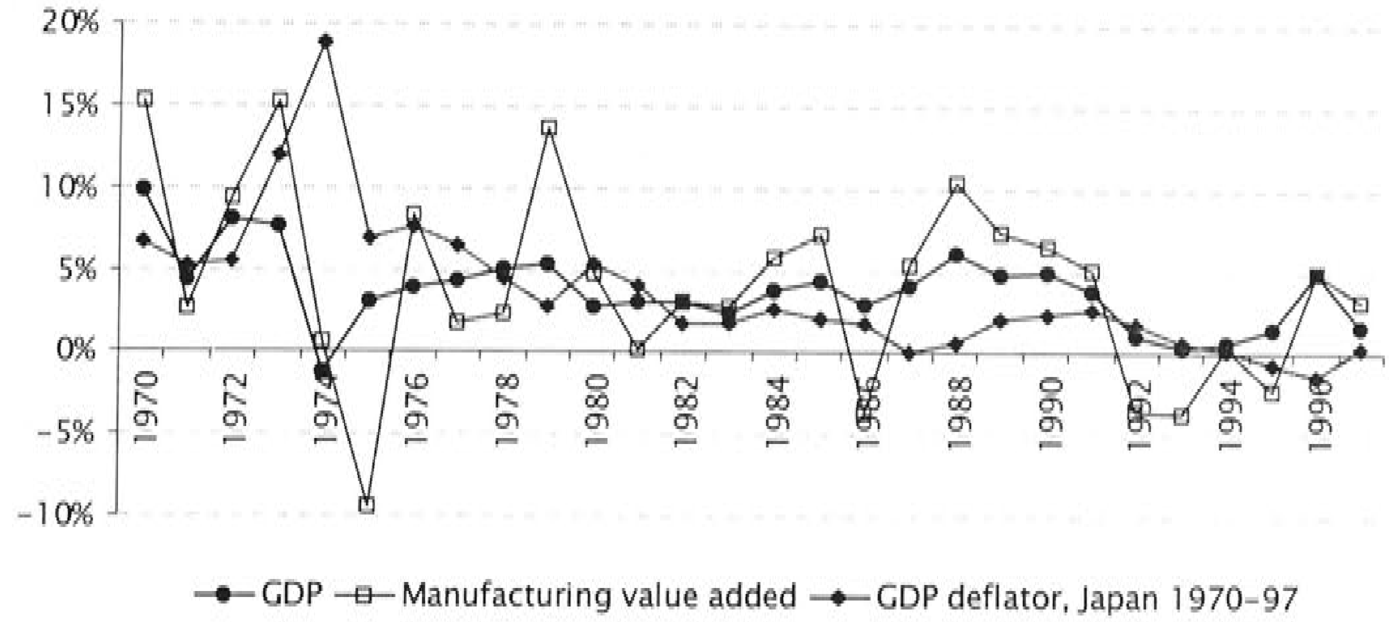
Source: As in Figure 4.1.

Figure 4.3 presents manufacturing share in GDP and the ratio of manufacturing GFCF to manufacturing value added in Hong Kong. It is understood that the manufacturing share in GDP has been decreasing over time since the mid-1980s. At the beginning of the 1980s, manufacturing value added still accounted for over 25% of GDP but dropped to only 6.6% in 1997. The manufacturing share in GDP in the 1970s, 1980s and 1990s was on average 27.1%, 20.8% and 9.8%, respectively. In terms of the ratio of manufacturing GFCF to manufacturing value added, the highest ratio recorded was 16.4% in 1986 falling to 7.9% in 1994. Regardless of the relatively stable ratio in the past two decades, the result indicates that manufacturing GFCF was declining at a similar speed to manufacturing value added.

4.1.2 Japan

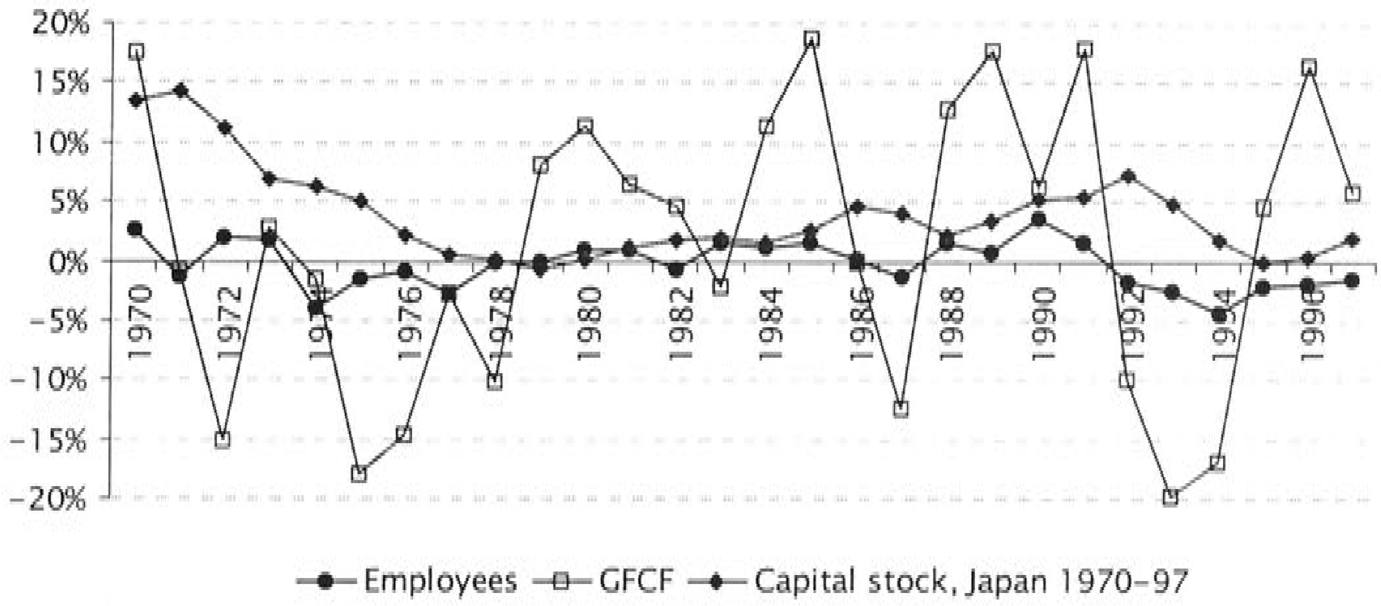
Figure 4.4 shows the average annual real growth rates of economy GDP, manufacturing value added and GDP deflator in Japan for the 1970–97 period. The average annual growth rate of GDP was similar to that of manufacturing value added. Yet, the latter apparently fluctuated more than the former and even turned negative in 1975, 1986, 1992–93 and 1995. The rate of inflation was high in the early 1970s featured by the oil crisis but it stabilised after the late 1970s. Nevertheless, the Japanese economy has been in trouble since 1990 causing deflation over the period 1994–95.

Figure 4.4 Average annual real growth rates: GDP, manufacturing value added and GDP deflator in Japan



Sources: Author's calculation based on *dX* for Windows 3.0, EconData: CEIC Database, Japan and UNIDO database.

Figure 4.5 Average annual growth rates: number of employees, real GFCF and real capital stock in Japan's manufacturing

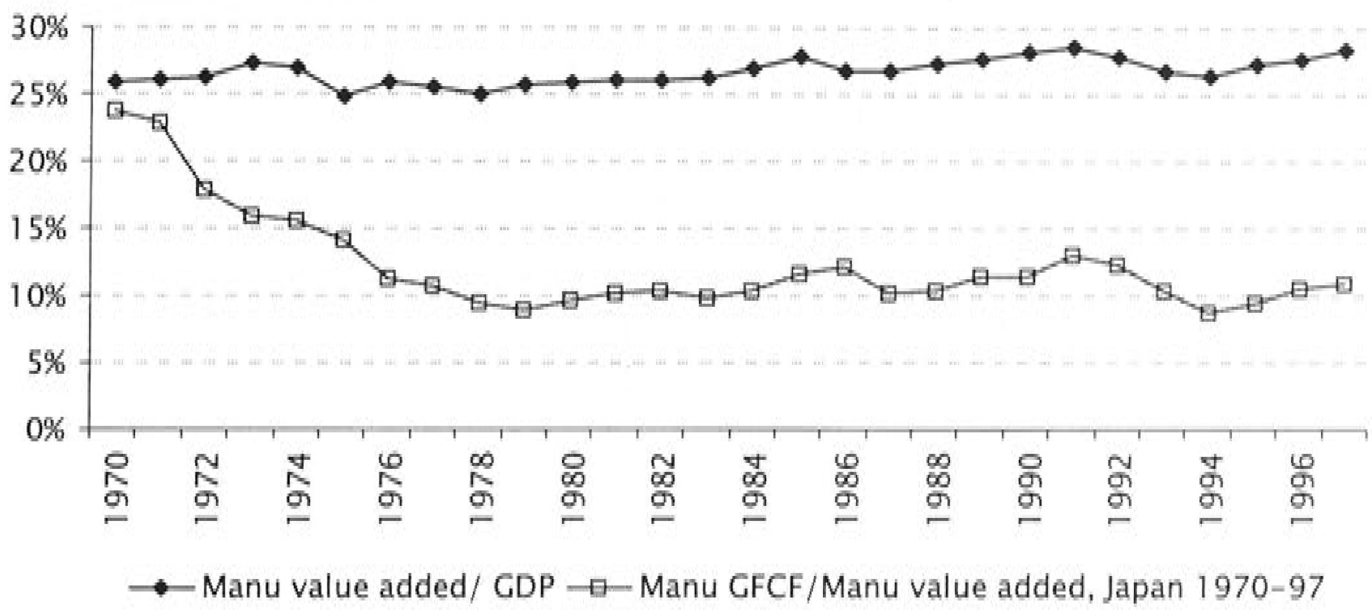


Source: As in Figure 4.4.

The number of employees decreased during the periods 1974–79 and 1992–97 as seen in Figure 4.5. When fewer workers are employed, it may signal that less physical capital investment is required. Moreover, the average annual growth rate of GFCF was negative in both the 1974–78 and 1992–94 periods, which were to some degree corresponding to the fluctuation of manufacturing employment. In the end, the GFCF merely grew at a rate of 0.8% per annum. With regard to the growth rate of capital stock, except for 1978 and 1995 it has been always positive. However, even those two negative growth rates of capital stock were very small and negligible.

Figure 4.6 presents the manufacturing share in GDP and the ratio of manufacturing GFCF to manufacturing value added during the period 1970–97. Surprisingly, the manufacturing share in GDP ranges from 24.8% to 28.6% and has been steady over the past 27 years. To some extent, it reflects the imperative role of the manufacturing sector in Japan's economy. The ratio of manufacturing GFCF to manufacturing value added was above 20% in the early 1970s but fluctuated at around 9% to 12% from the late 1970s to the 1990s. The highest ratio recorded was 23.7% in 1970 and the lowest ratio was 8.8% in 1994. This implies that the amount of investment from Japan's manufacturers was based mostly on the actual value added produced. In other words, when the growth of valued added slowed, so did the growth of GFCF.

Figure 4.6 Manufacturing share in GDP and ratio of manufacturing GFCF to manufacturing value added in Japan

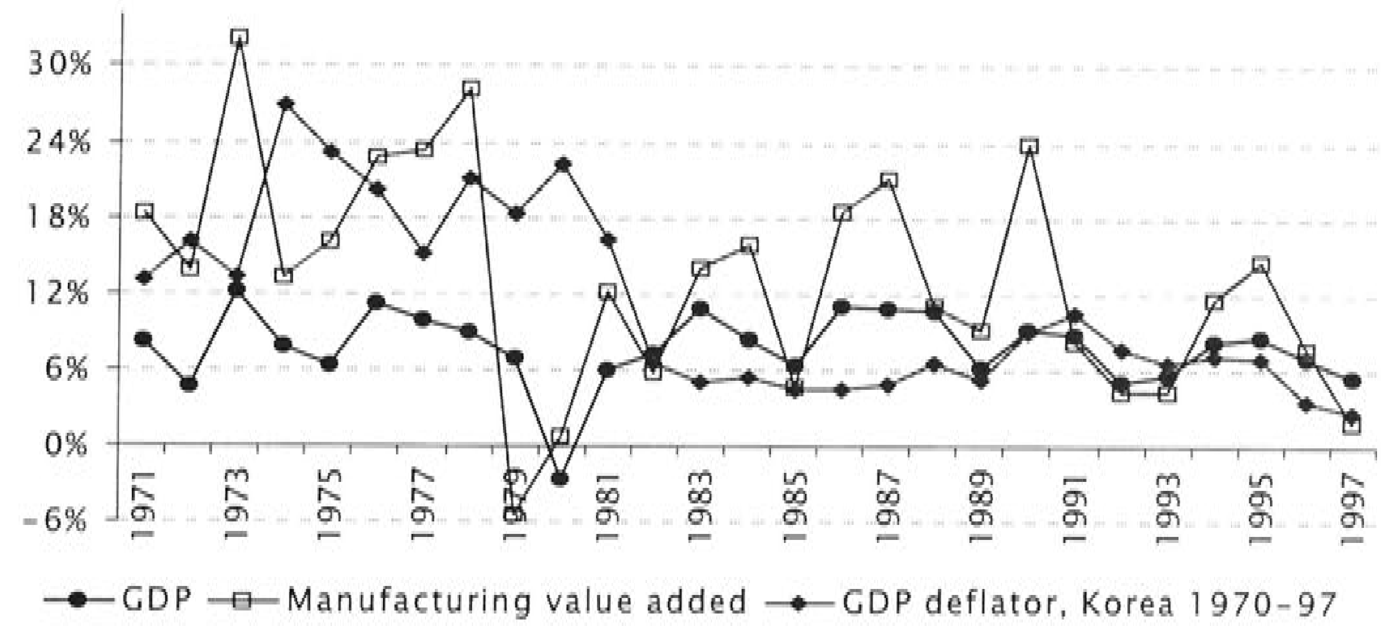


Source: As in Figure 4.4.

4.1.3 Korea

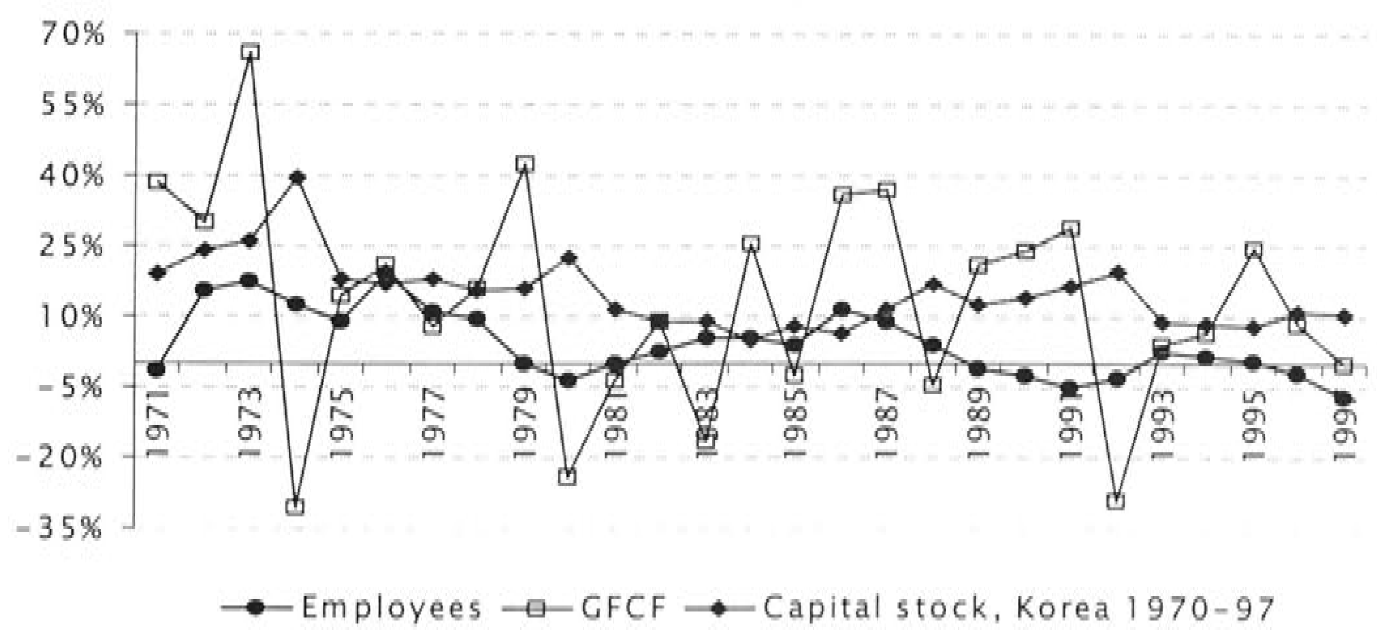
Apart from 1980, the Korean economy has been strong over the 1971–97 period and annual growth rates of GDP even achieved double digits in a number of years as shown in Figure 4.7. As an engine of the overall economy, the Korean manufacturing sector performed even better. The value added of the manufacturing sector on average grew by more than 20% during the 1971–78 period whereas negative output growth occurred in 1979, which was a significant outlier compared with other years. Despite this outstanding economic performance, an average annual inflation rate of nearly 19% prevailed throughout the 1970s. Except for 1981 and 1991 the inflation rate was under control in the 1980s and 1990s. In general, it fluctuated at around 6% in the 1980s, increasing to 10% in 1991, but decreasing again since then. In 1997, the inflation rate fell to only 2.6% in 1997.

Figure 4.7 Average annual real growth rates: GDP, manufacturing value added and GDP deflator in Korea 1970–1997



Sources: Author's calculation based on *dX* for Windows 3.0, EconData: CEIC Database, Korea and UNIDO database.

Figure 4.8 Average annual growth rates: number of employees, real GFCF and real capital stock in Korea's manufacturing 1970–1997

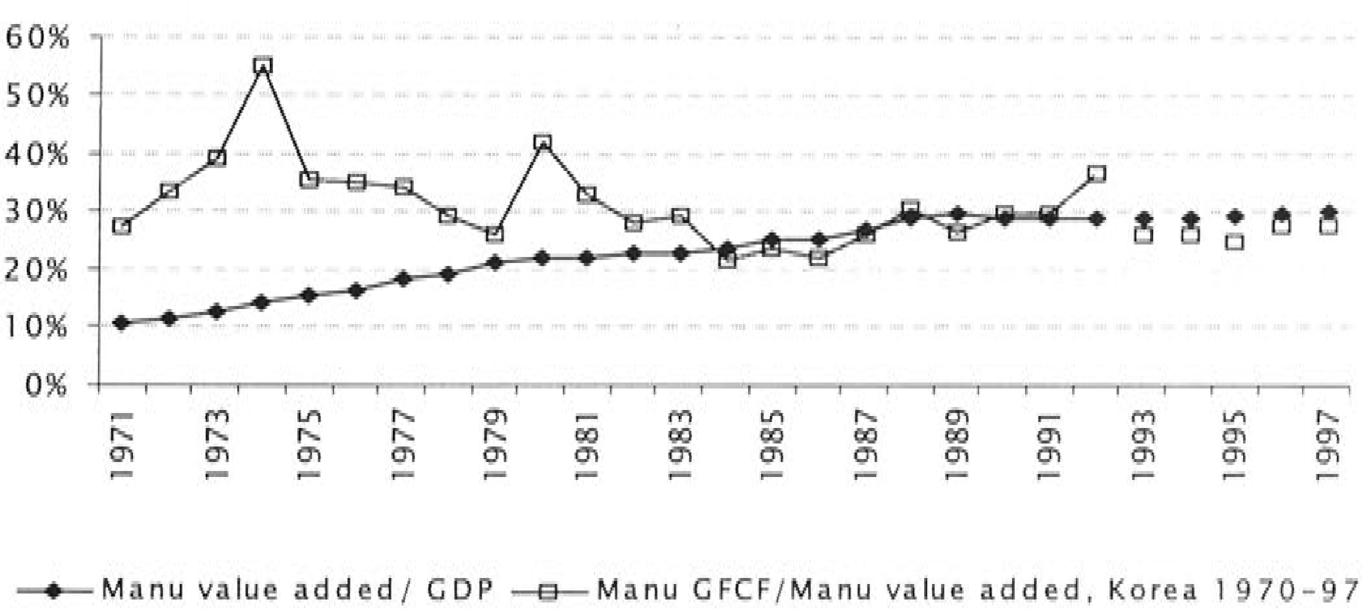


Source: As in Figure 4.7.

Figure 4.8 shows that except for 1971 the number of employees in the manufacturing sector grew significantly in the 1970s. In the early 1980s, the expansion of manufacturing employees slowed and even became negative in 1980 and 1981. After that, the growth in employee numbers began increasing until 1986. Numbers of employees fell during the 1989–1992 period. In general, the average annual growth rate of the number of employees was negative in the 1990s. Regarding the growth rate of GFCF, it was 65.8% in 1973 but in the subsequent year it dropped considerably to –30.4%. A similar scenario also took place in other periods such as 1979–80; nevertheless, the trend of GFCF growth was declining. The growth rate of capital stock always stayed positive during the sample period.

As shown in Figure 4.9, unlike other East Asian manufacturing sectors, the manufacturing share in GDP in Korea has risen from 10.6% in 1971 to 29.1% in 1988. Since then, the share has been maintained at between 29% and 30%. The highest ratio of manufacturing GFCF to manufacturing value added occurred in 1974 and was over 30% for most of the 1970s. Apart from 1992 (36.6%), the ratio moved back and forth between 20% and 30% in the 1980s and 1990s.

Figure 4.9 Manufacturing share in GDP and ratio of manufacturing GFCF to manufacturing value added in Korea 1970–1997



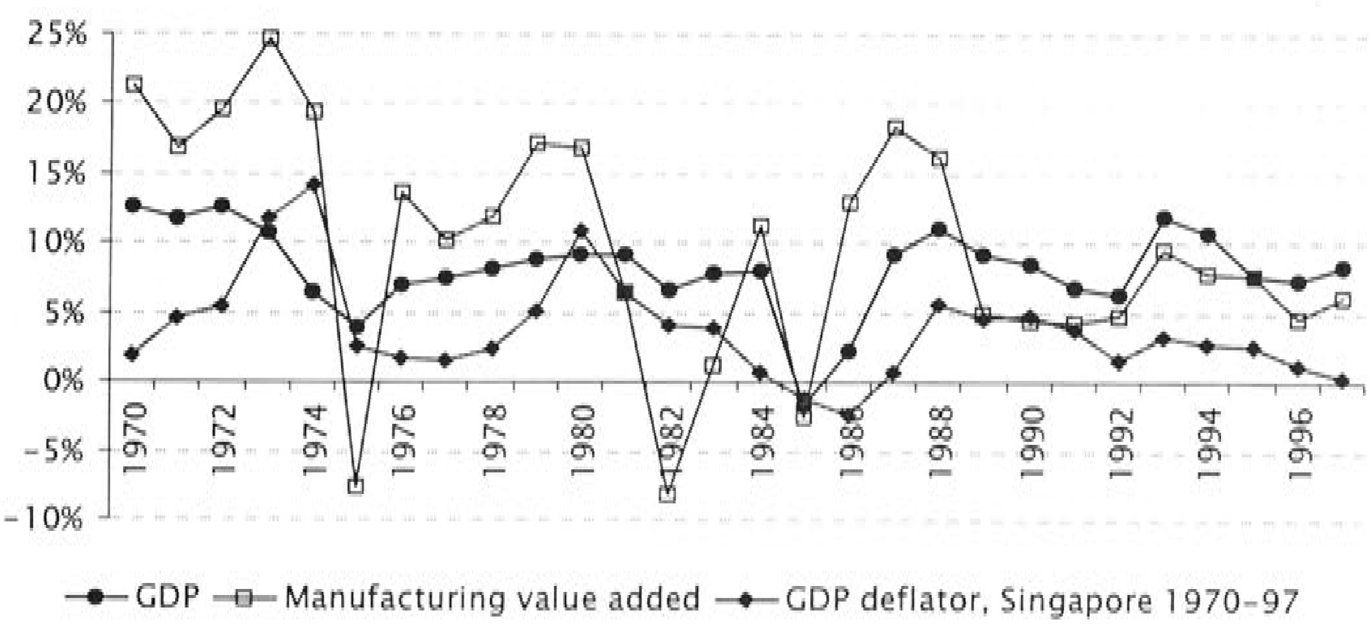
Source: As in Figure 4.7.

4.1.4 Singapore

Figure 4.10 indicates that Singapore's economy grew spectacularly over the past three decades except for 1985, which experienced negative growth of 1.6%. In terms of output growth, the manufacturing sector performed better than the overall economy in the 1970s but the overall economy in general outperformed the manufacturing sector in the 1980s and 1990s. The manufacturing sector experienced negative output growth in 1975, 1982 and 1985. The inflation rate has been low in Singapore since the early 1980s but deflation occurred in 1985 and 1986 due mainly to economic recession. On average, the rate of inflation was below 3% over the past two decades.

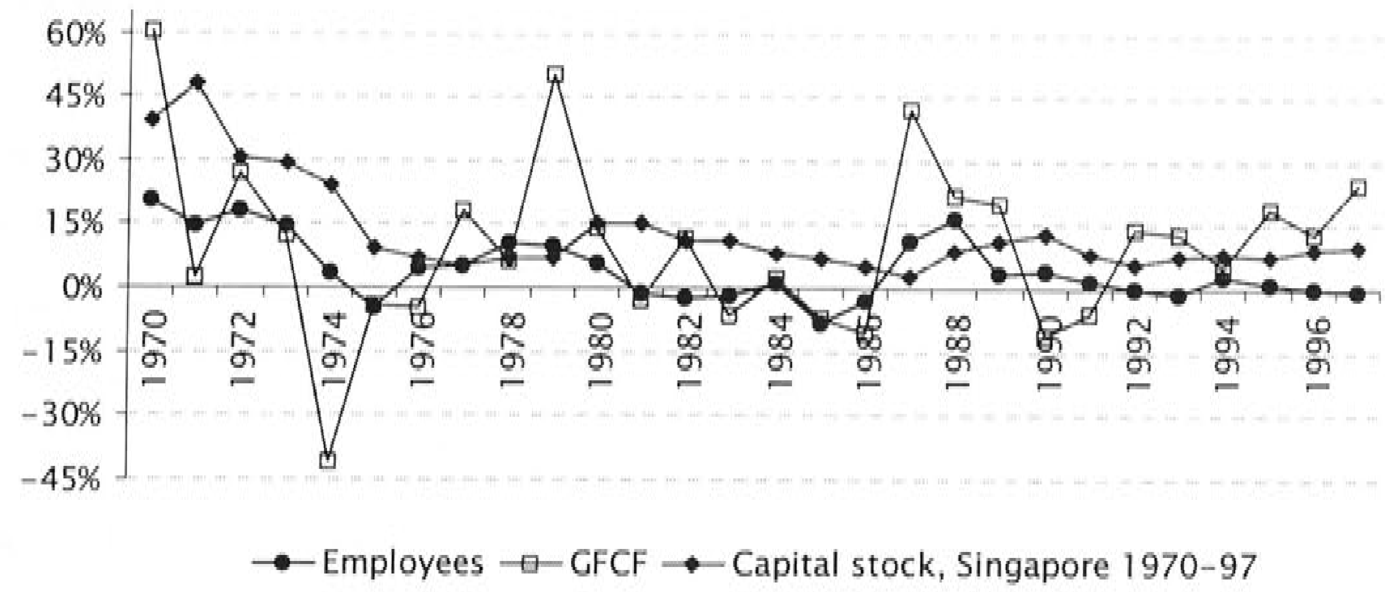
The number of employees in the manufacturing sector increased rapidly in the 1970s but experienced negative growth in the periods 1981–83 and 1985–86 as seen in Figure 4.11. In the following two years, 1987 and 1988, the number of employees grew by 11.2% and 16.2%, respectively. In the 1990s, there was very little growth in the number of employees. Despite the sharp fluctuation in the 1970s, the average annual growth rate of GFCF was still maintained at over 10% in the 1970s and 1990s. After the economic recession in the period 1985–86, there was considerable growth in GFCF in 1987. The growth rate of capital stock has been positive and steady since the mid-1970s.

Figure 4.10 Average annual real growth rates: GDP, manufacturing value added and GDP deflator in Singapore



Sources: Author's calculation based on *dX* for Windows 3.0, EconData: CEIC Database, Singapore and UNIDO database.

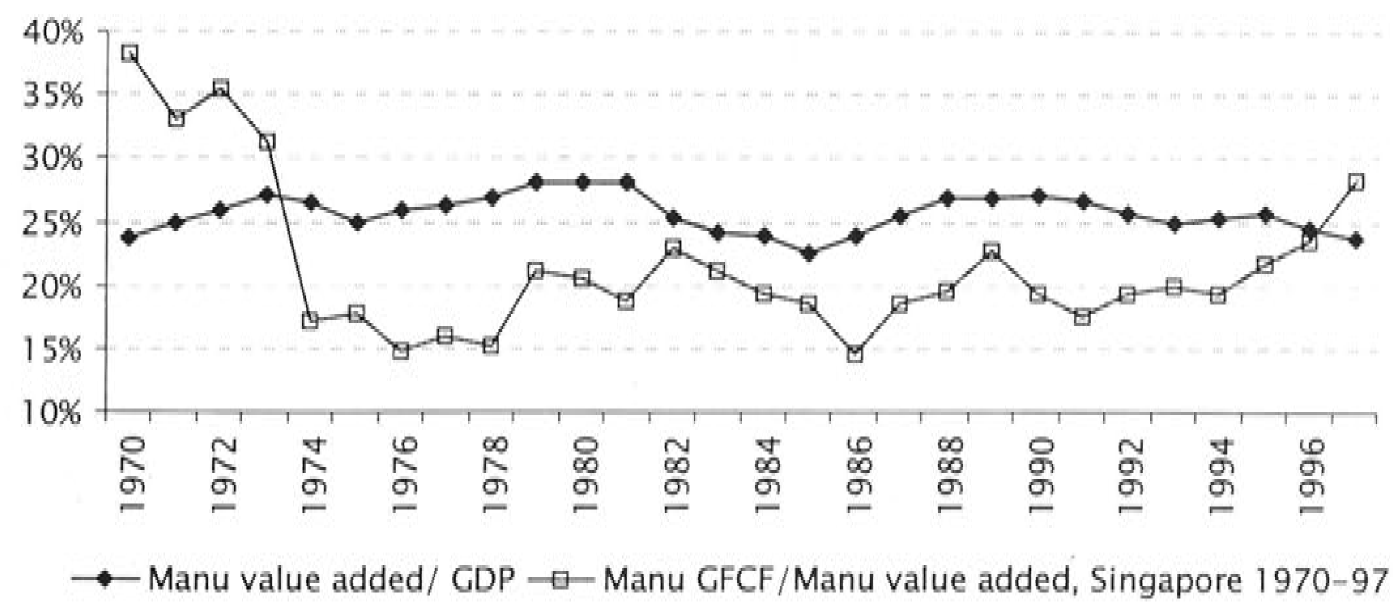
Figure 4.11 Average annual growth rates: number of employees, real GFCF and real capital stock in Singapore's manufacturing 1970–97



Source: As in Figure 4.10.

According to Figure 4.12, the manufacturing share in GDP in Singapore ranged from 22.5% (1985) to 28.2% (1980) during the sample period. In general, the share was above 25% with the exception of small declines in the early 1970s, and the 1982–86 and 1996–97 periods. The ratio of manufacturing GFCF to manufacturing value added was over 30% in the early 1970s but declined to 15.1% in 1978. Then, the ratio varied between 17% and 23% from the 1980s until the mid-1990s. In 1997, the ratio increased to 28.3%.

Figure 4.12 Manufacturing share in GDP and ratio of manufacturing GFCF to manufacturing value added in Singapore 1970–97

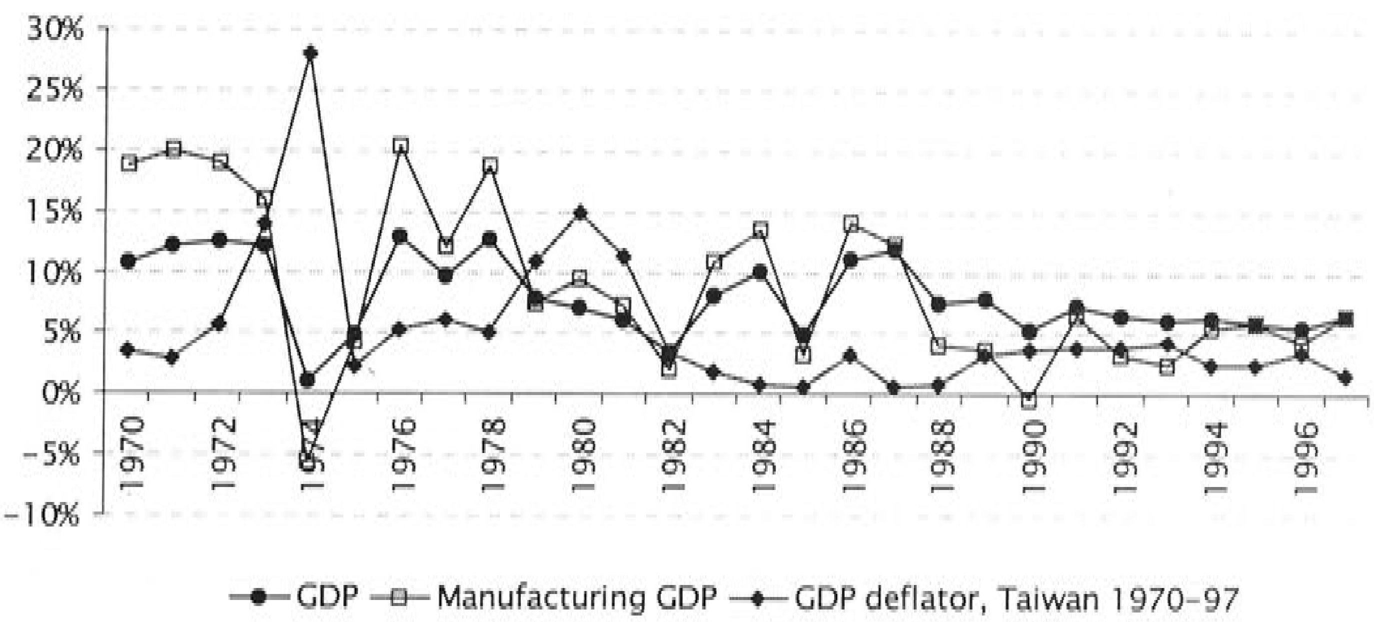


Source: As in Figure 4.10.

4.1.5 Taiwan

Analogous to Singapore, Taiwan's economy also enjoyed double-digit growth in the early 1970s. Although the growth rates of the overall economy slowed in the 1980s and 1990s, as indicated by Figure 4.13 they have been positive over the past three decades. With respect to output growth, the manufacturing sector outperformed the entire economy in the 1970s but suffered negative growth in 1974 and 1990. Nonetheless, the economy grew better than the manufacturing sector in the 1980s and 1990s. The average annual inflation rate was about 9% in the 1970s and the highest inflation rate was recorded in 1974 due to the oil crisis. Following the second oil crisis in 1980, the inflation rate has been approximately 3% since 1982.

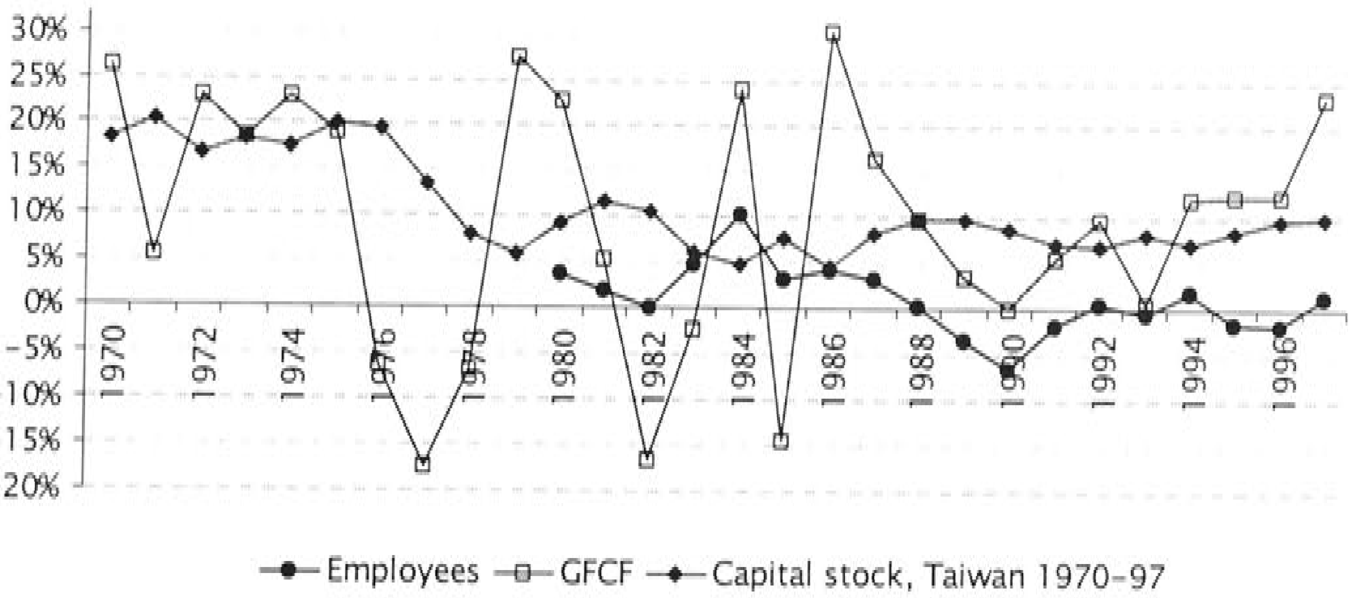
Figure 4.13 Average annual real growth rates: GDP, manufacturing value added and GDP deflator in Taiwan



Source: Author's calculation based on *dX* for Windows 3.0, EconData: CEIC Database, Taiwan.

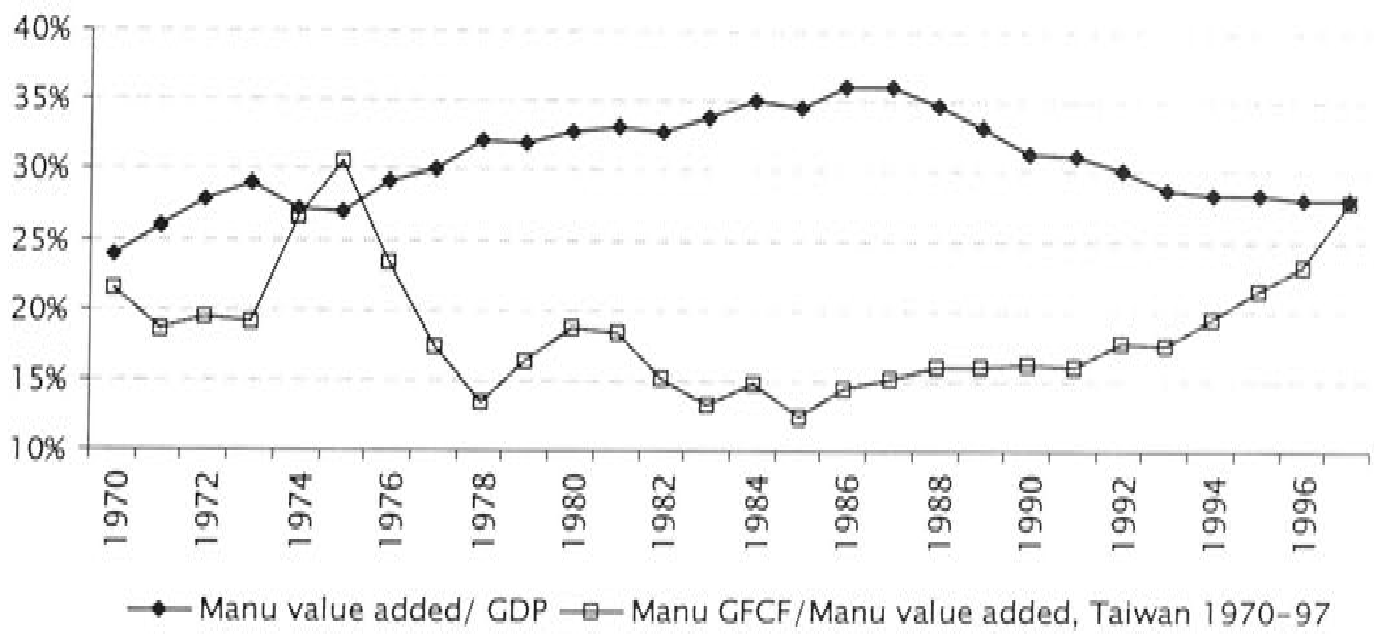
Employment growth in the manufacturing sector was limited in Taiwan as shown in Figure 4.14. Despite high employment growth in 1984, it was soon offset by negative growth in 1989 and 1990. The number of employees on average increased by 1.8% per annum during the 1980s but decreased in the 1990s. Similar to other economies, the growth of GFCF in Taiwan's manufacturing industries fluctuated drastically, and manufacturing's GFCF even experienced negative growth in 1976–78 and 1982–83 periods as well as in 1985. The growth rate of capital stock was roughly about 15% in the 1970s but it decelerated to around 8% in the 1980s and 1990s.

Figure 4.14 Average annual growth rates: number of employees, real GFCF and real capital stock in Taiwan's manufacturing



Source: Author's calculation based on *dX* for Windows 3.0, EconData: CEIC Database, Taiwan and the DGBAS (GFCF).

Figure 4.15 Manufacturing share in GDP and ratio of manufacturing GFCF to manufacturing value added in Taiwan 1970–97



Source: As in Figure 4.14.

As indicated in Figure 4.15, the share of manufacturing output was roughly 26% of GDP at the outset. As an engine of Taiwan's economy, the manufacturing sector soon increased its GDP share over time. The highest share of 38.4% took place in 1986 and 1987, and was the highest among the five East Asian manufacturing sectors. Since then, the manufacturing share in GDP has dropped to nearly 30%. The highest ratio of manufacturing GFCF to manufacturing value added occurred in 1975 and the lowest was in 1985. Average ratios were about 22%, 16% and 20% in the 1970s, 1980s and 1990s, respectively.

4.1.6 Economic Indicators in the Five East Asian Manufacturing: A Summary

Table 4.1 Average annual growth rates: GDP, manufacturing value added, employees, GFCF and capital stock and average manufacturing share in GDP and GFCF share in manufacturing value added (percent)

Countries	Periods	GDP	Manu value added	Employees	GFCF	Capital stock	Manu GDP/ GDP	Manu GFCF/ manu value added
Hong Kong	1976–80	9.9	8.1	3.7	3.6	4.3	27.1	14.0
	1980–90	6.3	1.6	-2.9	1.4	3.5	20.8	12.7
	1990–97	5.0	-7.6	-13.2	-9.7$	-1.3	9.7	11.5$
	1976–97	6.6	-0.2	-5.1	-1.5$	2.0	18.7	12.6$
Japan	1970–80	4.3	5.0	-0.6	-4.1	4.6	25.9	14.5
	1980–90	3.9	4.5	0.9	6.3	2.8	27.0	10.8
	1990–97	2.0	0.6	-1.8	-0.2	3.0	27.6	10.8
	1970–97	3.6	3.7	-0.4	0.8	3.5	26.8	11.8
Korea	1970–80	7.3	16.3	8.9	18.3	21.5	16.2	35.7
	1980–90	8.7	13.6	3.8	12.6	10.4	25.7	27.1
	1990–97	6.9	7.5	-1.8	6.2	11.8	29.4	28.5
	1970–97	7.7	13.0	4.3	13.0	14.9	23.1	30.7
Singapore	1970–80	8.6	14.2	8.3	8.1	18.3	26.2	23.6
	1980–90	7.0	6.5	2.0	5.9	9.4	25.4	19.5
	1990–97	8.5	6.4	0.7	11.8	8.3	25.2	21.4
	1970–97	8.0	9.4	4.0	8.3	12.4	25.7	21.6
Taiwan	1970–80	9.3	12.2	NA	10.9	14.9	28.8	20.4
	1980–90	7.6	7.1	1.8	5.6	8.2	34.1	15.2
	1990–97	6.3	4.9	-0.3	10.9	8.3	28.9	20.5
	1970–97	7.9	8.4	1.1*	8.9	10.7	30.7	18.6

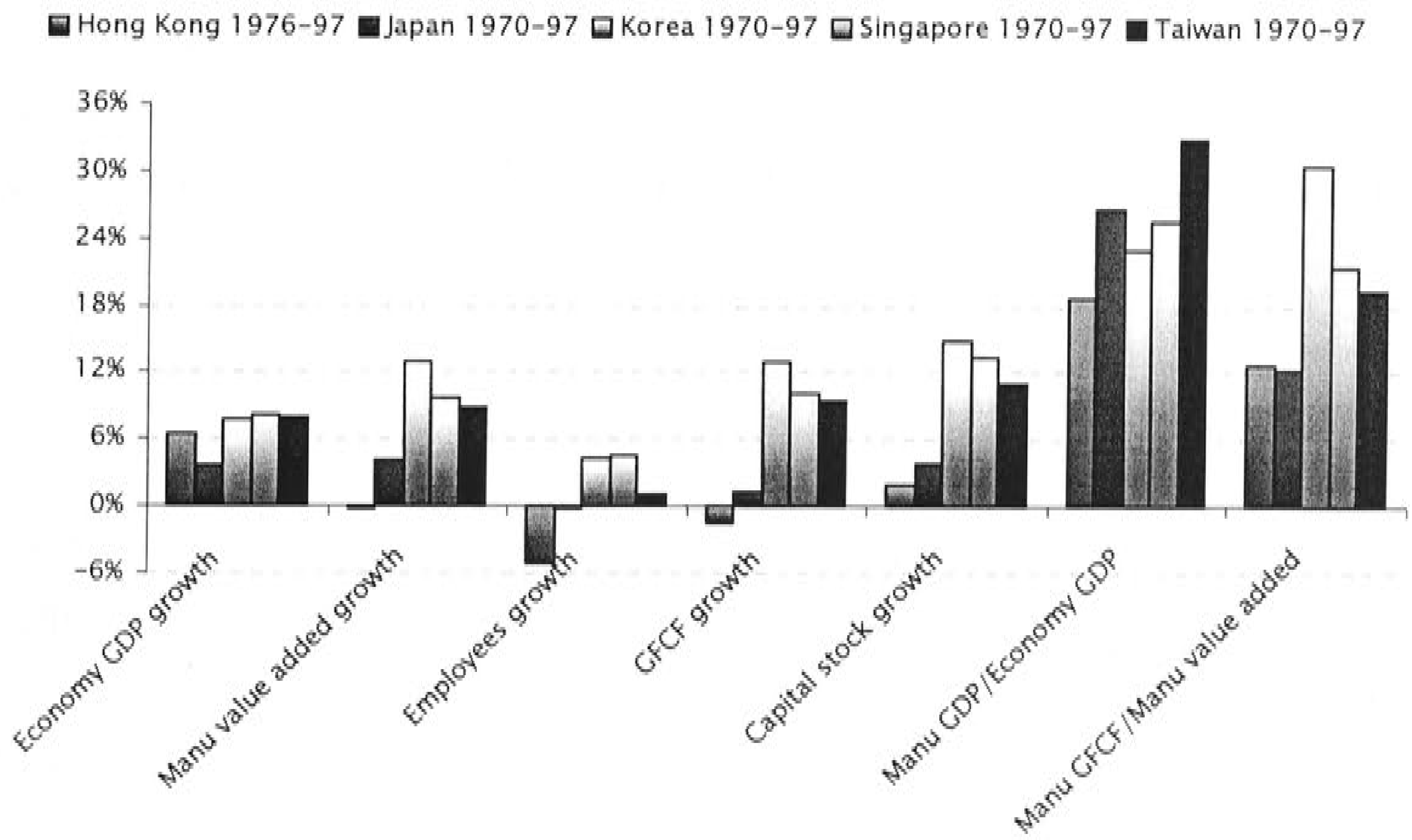
Notes: 1. ($) denotes the period to 1996 only and (*) the period from 1980 to 1997.
2. NA: not available.

Source: Author's calculation based on *dX* for Windows 3.0, EconData: CEIC Database, UNIDO database and the DGBAS (Taiwan's GFCF).

Table 4.1 presents a summary of the economic indicators of the five East Asian manufacturing sectors. Among the five economies, the highest average annual growth rate of GDP over the past three decades was in Singapore with 8.2%, followed by Taiwan with 8%, Korea with 7.7%, Hong Kong with 6.6% and Japan with 3.6%. In terms of manufacturing output growth, Korea had the highest average annual output growth rate of 13%, followed by Singapore (9.8%), Taiwan (8.8%), and Japan (3.7%). However, Hong

Kong's manufacturing sector was the only one to receive –0.2% output growth because of the relocation of its manufacturing production to mainland China since the mid-1980s. Correspondingly, it comes as no surprise that the growth rate of employee numbers in Hong Kong was negative (–5.1%). In Japan, there was small negative growth of 0.4% in manufacturing employment. In contrast, Singapore, Korea, and Taiwan increased manufacturing employment by 4.6%, 4.3% and 1.1% per annum, respectively. Similarly, the average annual growth rate of GFCF was negative in Hong Kong (–1.5%) and relatively small in Japan (1.4%). But, there was substantial growth of GFCF in the other three economies, with 13% in Korea, 10.1% in Singapore, and 9.6% in Taiwan. These economic indicators for the five East Asian manufacturing sectors over the past three decades (two decades for Taiwan) are graphed in Figure 4.16.

Figure 4.16 Average annual growth rates: GDP, manufacturing value added, employees, GFCF and capital stock and average manufacturing share in GDP and GFCF share in manufacturing value added (percent)



Source: As in Table 4.1.

The growth rates for manufacturing capital stock were positive across the five manufacturing sectors; particularly, Korea recorded the highest growth rate of 14.9%, followed by Singapore (13.4%), Taiwan (11%), Japan (3.9%) and Hong Kong (2%). With regard to manufacturing share in GDP, on average Taiwan had the highest share of 33.1%. For Japan, Korea, and Singapore, shares were somewhere between 25% and 30%. Due to the share falling below 10% in the 1990s, Hong Kong's manufacturing sector on average contributed only 18.7% to GDP. The average ratio of manufacturing GFCF to manufacturing value added in Korea was 30.7% between 1970 and 1997; in other words, Korean manufacturing industries invested more than 30% of its value added in GFCF. Both Singapore and Taiwan devoted about 20% of manufacturing value added to GFCF. The investment in GFCF was very small in Hong Kong and Japan, roughly only about 12% of output. Overall, the Korean manufacturing sector had the highest average annual growth rates of manufacturing value added, GFCF, and capital stock, followed by Singapore and Taiwan.

4.2 RESULTS OF THE BREUSCH-PAGAN LM TEST

In this section, the conventional assumption of homogeneously applying the best practice technology is tested by employing the Breusch-Pagan LM test outlined in section 3.3.1. Table 4.2 reports the Breusch-Pagan test statistics using the computer program *SHAZAM*. This test will statistically reaffirm the use of the varying coefficients frontier model if the null hypothesis of the homogeneous application of production technology is rejected. As can be seen in Table 4.2, the hypothesis of homogeneity across industries is statistically rejected for Korean manufacturing industries apart from the period 1970–82 and the year 1997 and for Singaporean manufacturing industries except for the periods 1974–77, 1979–80 and 1985–86 and the year 1983. Hence, the results strongly support the specification of the varying coefficients frontier model in the cases of Korea and Singapore (Breusch and Pagan, 1979). Intuitively, the interpretation of the statistical results is that manufacturing industries in Korea and Singapore always utilised their production technology and resources in different ways regardless of having the same access to the frontier production technology. In other words, the actual input-specific response coefficients did vary across industries. In contrast, the conventional constant-slope frontier production function, which cannot reflect the random variation in coefficients, has been rejected through the Breusch-Pagan test.

Although Table 4.2 does not statistically favour the manufacturing sectors of Hong Kong, Japan, and Taiwan, random variation in the estimated coefficients across industries cannot be ruled out. In most cases, there are certain variations in the estimated coefficients of labour input, which despite being small indicate industries applied their human resources differently. Although the heterogeneity of manufacturing industries has been rejected in those three sectors, it is theoretically justified to model the variation in the labour and capital coefficients of industries.

Table 4.2 The results of the Breusch-Pagan LM test for manufacturing industries in the five East Asian manufacturing industries

Year	Hong Kong	Japan	Korea	Singapore	Taiwan
1965	—	8.797*	—	—	—
1966	—	8.196*	—	—	—
1967	—	12.105*	—	—	—
1968	—	13.627*	—	—	—
1969	—	10.327*	—	—	—
1970	—	9.752*	0.476	10.486*	—
1971	—	5.492**	0.507	12.316*	—
1972	—	3.206	0.072	16.293*	—
1973	—	1.479	1.061	9.157*	—
1974	—	4.904**	0.184	2.487	—
1975	—	3.565	0.073	4.513	—
1976	0.171	1.638	0.018	2.002	—
1977	0.344	1.587	1.983	1.304	—
1978	0.767	0.478	0.175	6.517*	—
1979	1.834	0.784	1.111	1.71	—
1980	0.482	1.346	0.164	3.726	—
1981	2.927	1.125	1.053	10.197*	1.873
1982	2.645	1.191	3.753	6.55*	0.995
1983	2.883	0.319	8.615*	1.209	1.128
1984	2.849	0.691	11.729*	9.711*	1.119
1985	1.924	0.392	10.473*	3.787	1.070
1986	13.237*	0.243	14.269*	3.915	1.155
1987	2.512	0.042	8.955*	4.93**	1.407
1988	0.505	0.534	11.750*	7.831*	1.994
1989	2.323	1.525	10.588*	8.564*	1.692
1990	0.755	4.181	10.136*	10.639*	1.613
1991	0.398	4.746**	8.378*	12.423*	1.745
1992	0.782	3.285	7.393*	11.563*	1.488
1993	0.990	0.416	5.402**	14.760*	2.502
1994	4.911**	0.791	7.444*	13.682*	3.164
1995	7.306*	0.57	12.343*	17.066*	6.322*
1996	9.738*	1.667	10.713*	15.500*	8.136*
1997	2.840	1.715	2.673	11.918*	7.228*
1998	—	2.023	—	—	5.573**
1999	—	—	—	—	1.613

Note: * and ** represent statistical significance at the 5% and 10% levels, where the critical values of a χ^2 distribution with 2 degrees of freedom at the 5% and 10% significance levels are 5.99 and 4.61, respectively.

4.3 Estimates of Varying Coefficients

Irrespective of differences in nature across manufacturing industries at the 3-digit level, the underlying assumption behind the estimation is that industries have the same opportunity to access frontier technology, i.e., sharing the best-practice production frontier. Nevertheless, various applications of frontier technology leading to different output are always observed. Following the specification of the varying coefficients frontier model, the frontier production function is estimated using the computer program *TERAN* developed by Kalirajan and Obwona (1994) at the Australian National University for individual countries and individual manufacturing industries. The ranges of actual response coefficients, i.e., estimated minimal and maximal (frontier) coefficients, and mean coefficients of the five East Asian manufacturing sectors are presented in Tables 4.3 to 4.7, respectively.[49] The average intercepts and labour and capital coefficients are reported at the bottom of each table. To save space, the t-ratios of the mean coefficients estimated by general least square are not reported here; however, those t-ratios are always statistically significant at the 5% or even 1% level.

Table 4.3 shows the estimates of frontier and mean coefficients of production function for Hong Kong's manufacturing sector over the period 1976–97. Due to the relatively larger labour coefficients, i.e. greater than 0.8, since 1992, the estimated frontier coefficients for Hong Kong were not satisfactory. As the data became increasingly volatile in the 1990s, such outcome was in part attributable to the removal of two additional industries, footwear and beverages, because tiny output-capital ratios were discovered in the footwear industry since 1993 and negative capital stock caused by the huge negative GFCF was found in the beverages industry in 1995 and 1996. To some extent, the structural transformation in the manufacturing industries in Hong Kong also contributed to this outcome.[50]

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[49] Due to the fact that the estimations for Hong Kong and Singapore manufacturing industries have encountered difficulties, one or two industries were removed temporarily in order to maintain the consistency of the frontier coefficients throughout the entire sample period.

[50] This refers to the rapid relocation of Hong Kong's manufacturing industries to mainland China since the mid-1980s, see Tuan and Ng (1995, 1997) for details.

Table 4.3 Estimates of frontier and mean coefficients of production function for Hong Kong's manufacturing, 1976–97

Year	Range of actual response coefficients: *Minimal varying coefficients*			Range of actual response coefficients: *Frontier coefficients (maximal)*			*Mean coefficients*		
	Constant	Labour	Capital	Constant	Labour	Capital	Constant	Labour	Capital
1976	7.915	0.493	0.374	8.202	0.571	0.374	8.045	0.528	0.374
1977	7.563	0.417	0.432	7.813	0.491	0.432	7.665	0.448	0.432
1978	8.416	0.530	0.337	8.785	0.597	0.337	8.627	0.567	0.337
1979	8.142	0.491	0.382	8.142	0.554	0.382	8.142	0.525	0.382
1980	7.600	0.462	0.409	7.662	0.541	0.409	7.637	0.509	0.409
1981	7.957	0.574	0.344	8.393	0.597	0.351	8.224	0.588	0.348
1982	7.489	0.543	0.384	7.850	0.583	0.384	7.668	0.562	0.384
1983	7.767	0.540	0.369	7.806	0.640	0.369	7.789	0.596	0.369
1984	7.524	0.645	0.334	7.805	0.682	0.334	7.681	0.664	0.334
1985	6.883	0.547	0.408	7.252	0.596	0.408	7.024	0.565	0.408
1986	6.476	0.535	0.426	6.867	0.613	0.426	6.686	0.574	0.426
1987	8.204	0.617	0.314	8.765	0.621	0.335	8.491	0.619	0.325
1988	5.994	0.478	0.482	6.466	0.536	0.482	6.238	0.506	0.482
1989	7.250	0.495	0.413	7.436	0.592	0.413	7.350	0.545	0.413
1990	7.704	0.609	0.335	7.909	0.730	0.335	7.805	0.668	0.335
1991	6.540	0.592	0.397	6.708	0.705	0.397	6.626	0.649	0.397
1992	8.904	0.812	0.188	9.658	0.856	0.199	9.288	0.833	0.193
1993	10.023	0.836	0.137	10.617	0.858	0.153	10.269	0.845	0.144
1994	10.714	0.903	0.068	11.386	0.903	0.099	11.047	0.903	0.082
1995	10.912	0.904	0.064	11.414	0.991	0.064	11.160	0.942	0.064
1996	9.450	0.860	0.157	9.703	0.860	0.185	9.558	0.860	0.169
1997	9.244	0.799	0.193	9.452	0.870	0.193	9.360	0.837	0.193
Average	8.121	0.622	0.316	8.459	0.681	0.321	8.290	0.652	0.318

Notes: 1. The minimal varying coefficients denote the lowest estimated coefficients among industries and the frontier coefficients are the largest ones among industries according to the specification of the model.
2. All random coefficients are averaged to obtain mean coefficients.

Source: Author's calculation using the computer program *TERAN*.

In terms of the magnitudes of the frontier coefficients, the capital coefficients exceed labour coefficients throughout the entire period. Sizable variations in the labour coefficients have been identified across industries during the sample period except in 1994 and 1996; for instance, the range of the labour coefficients in 1976 was between 0.493 and 0.571. One of the objectives of this study is to take industry-specific characteristics into account. Therefore, the result for Hong Kong has corresponded to the earlier expectation that industries applied their production technology and labour input (or human resources) differently because different industries require various types of skills in the production process. On the other hand, the variations in capital coefficients appeared to be small indicating that application of capital inputs across 21 manufacturing industries was reasonably similar.

With respect to returns to scale, it is possible that the sum of frontier labour and capital coefficients will exceed unity as estimated frontier coefficients are selected from the largest coefficients among various actual response coefficients. Put differently, if industry A utilises labour input most efficiently and industry C applies capital input most productively, then the frontier labour and capital coefficients will be chosen from industries A (labour coefficient) and C (capital coefficient), respectively.[51] Building on estimated frontier coefficients, the returns to scale for Hong Kong's manufacturing industries ranged from 0.923 in 1977 to 1.102 in 1991 as shown in Table 4.3. Discussion of the estimated frontier coefficients for the other four East Asian manufacturing sectors is briefly described as follows.

Table 4.4 presents the estimates of frontier and mean coefficients of production function for Japan's manufacturing sector over the period 1963–98. The estimated frontier capital coefficients in Japan were generally larger than the frontier labour coefficients. The extent of variations in labour coefficients ranged from 0.027 in 1964 to 0.095 in 1988 and the returns to scale ranged from 0.948 in 1975 to 1.053 in 1990. Yet, the variations in capital coefficients appeared to be zero.

Table 4.5 shows the estimates of frontier and mean coefficients of production function for Korea's manufacturing sector for the period 1970–97. In the early years of the sample period, the application of labour inputs differed considerably across industries due to the significant variation in labour coefficients but these differences were reduced in the later years. This implies that a number of Korean manufacturing industries that used to apply labour inputs less efficiently caught up with the most efficient industry of applying labour input. In line with Hong Kong and Japan's manufacturing industries, the degree of variation in capital coefficients seemed small in Korea. The returns to scale according to the estimated frontier coefficients varied from 0.936 in 1979 to 1.193 in 1972.

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[51] The possibility of estimated labour and capital coefficients chosen from the same industry cannot be completely ruled out.

Table 4.4 Estimates of frontier and mean coefficients of production function for Japan's manufacturing, 1965–1998

Year	Range of actual response coefficients								
	Minimal varying coefficients			*Frontier coefficients (maximal)*			*Mean coefficients*		
	Constant	Labour	Capital	Constant	Labour	Capital	Constant	Labour	Capital
1965	8.060	0.442	0.490	8.414	0.478	0.490	8.190	0.455	0.490
1966	7.954	0.487	0.473	8.243	0.535	0.473	8.087	0.506	0.473
1967	7.499	0.459	0.505	7.754	0.513	0.505	7.630	0.484	0.505
1968	7.478	0.477	0.497	7.888	0.525	0.497	7.695	0.499	0.497
1969	8.007	0.483	0.483	8.437	0.523	0.483	8.197	0.499	0.483
1970	8.380	0.495	0.466	8.830	0.533	0.466	8.576	0.510	0.466
1971	8.740	0.481	0.461	9.219	0.518	0.461	8.911	0.494	0.461
1972	9.544	0.522	0.412	9.809	0.579	0.412	9.667	0.545	0.412
1973	9.197	0.506	0.434	9.309	0.575	0.434	9.257	0.538	0.434
1974	9.071	0.460	0.466	9.409	0.496	0.466	9.199	0.472	0.466
1975	10.111	0.518	0.398	10.643	0.550	0.398	10.288	0.529	0.398
1976	10.345	0.527	0.382	10.665	0.589	0.382	10.502	0.553	0.382
1977	10.307	0.532	0.387	10.759	0.575	0.387	10.487	0.547	0.387
1978	10.238	0.558	0.381	10.665	0.600	0.381	10.372	0.570	0.381
1979	9.613	0.486	0.437	9.890	0.543	0.437	9.729	0.507	0.437
1980	9.134	0.454	0.468	9.565	0.502	0.468	9.318	0.473	0.468
1981	9.192	0.458	0.467	9.737	0.489	0.467	9.379	0.469	0.467
1982	8.966	0.471	0.468	9.418	0.515	0.468	9.149	0.486	0.468
1983	9.113	0.494	0.450	9.603	0.546	0.450	9.325	0.513	0.450
1984	8.633	0.501	0.461	9.021	0.563	0.461	8.831	0.529	0.461
1985	8.897	0.514	0.446	9.060	0.598	0.446	8.984	0.553	0.446
1986	9.364	0.534	0.426	9.694	0.596	0.426	9.494	0.555	0.426
1987	9.079	0.497	0.450	9.398	0.571	0.450	9.227	0.526	0.450
1988	8.887	0.492	0.460	8.950	0.587	0.460	8.920	0.535	0.460
1989	8.942	0.508	0.459	9.051	0.584	0.459	8.984	0.534	0.459
1990	8.971	0.548	0.440	9.229	0.613	0.440	9.066	0.570	0.440
1991	8.772	0.499	0.469	8.924	0.569	0.469	8.835	0.525	0.469
1992	8.640	0.471	0.485	8.944	0.528	0.485	8.759	0.491	0.485
1993	8.216	0.438	0.512	8.630	0.489	0.512	8.372	0.456	0.512
1994	9.033	0.427	0.487	9.370	0.488	0.487	9.183	0.451	0.487
1995	9.449	0.494	0.445	9.833	0.551	0.445	9.590	0.514	0.445
1996	9.362	0.516	0.440	9.896	0.559	0.440	9.550	0.531	0.440
1997	9.162	0.546	0.434	9.706	0.589	0.434	9.346	0.561	0.434
1998	9.625	0.547	0.420	10.026	0.592	0.420	9.752	0.560	0.420
Average	8.920	0.493	0.455	9.279	0.545	0.455	9.065	0.513	0.455

Note and source: As in Table 4.3.

Table 4.5 Estimates of frontier and mean coefficients of production function for Korea's manufacturing, 1970–1997

Year	Range of actual response coefficients						Mean coefficients		
	Minimal varying coefficients			*Frontier coefficients (maximal)*					
	Constant	Labour	Capital	Constant	Labour	Capital	Constant	Labour	Capital
1970	9.514	0.859	0.232	10.654	0.930	0.232	10.206	0.900	0.232
1971	8.115	0.772	0.322	9.169	0.868	0.322	8.774	0.830	0.322
1972	8.138	0.630	0.379	8.187	0.814	0.379	8.171	0.744	0.379
1973	8.417	0.616	0.388	9.437	0.687	0.396	8.968	0.653	0.392
1974	7.858	0.567	0.419	8.246	0.709	0.419	8.110	0.657	0.419
1975	7.849	0.622	0.406	8.769	0.672	0.418	8.377	0.649	0.413
1976	7.970	0.584	0.425	8.797	0.638	0.433	8.398	0.610	0.429
1977	7.854	0.418	0.511	8.565	0.479	0.511	8.160	0.442	0.511
1978	9.223	0.463	0.452	9.833	0.467	0.473	9.473	0.465	0.460
1979	9.052	0.376	0.492	9.409	0.444	0.492	9.184	0.402	0.492
1980	8.489	0.316	0.523	8.733	0.428	0.523	8.605	0.368	0.523
1981	8.507	0.399	0.491	9.187	0.469	0.491	8.849	0.436	0.491
1982	8.452	0.452	0.482	8.916	0.514	0.482	8.611	0.472	0.482
1983	8.648	0.436	0.481	9.269	0.483	0.484	8.895	0.454	0.482
1984	8.233	0.424	0.500	8.694	0.498	0.500	8.454	0.459	0.500
1985	7.984	0.395	0.519	8.476	0.466	0.519	8.233	0.430	0.519
1986	8.117	0.444	0.497	8.719	0.499	0.497	8.436	0.474	0.497
1987	8.200	0.476	0.487	8.817	0.521	0.490	8.503	0.497	0.489
1988	8.626	0.471	0.479	9.080	0.521	0.479	8.837	0.494	0.479
1989	8.676	0.466	0.484	9.018	0.522	0.484	8.811	0.487	0.484
1990	8.500	0.456	0.497	8.534	0.456	0.531	8.515	0.456	0.513
1991	9.524	0.598	0.406	9.900	0.598	0.425	9.710	0.598	0.415
1992	8.971	0.562	0.438	9.384	0.603	0.438	9.198	0.584	0.438
1993	9.356	0.548	0.429	9.413	0.633	0.429	9.386	0.591	0.429
1994	8.767	0.610	0.431	9.190	0.613	0.445	8.973	0.611	0.438
1995	7.716	0.610	0.467	8.156	0.610	0.480	7.989	0.610	0.476
1996	7.992	0.642	0.447	8.841	0.642	0.447	8.492	0.642	0.447
1997	7.524	0.637	0.465	8.425	0.637	0.465	8.014	0.637	0.465
Average	8.438	0.530	0.448	8.994	0.586	0.453	8.726	0.559	0.451

Note and source: As in Table 4.3.

Table 4.6 presents the estimates of frontier and mean coefficients of production function for Singapore's manufacturing sector during the 1970–97 period. It is interesting to note that certain variations in the labour coefficients occurred from the start of the sample period until the late 1980s. By contrast, there were some variations in the capital coefficients from the mid-1980s. The intuition behind the estimation outcome is that on the one hand, manufacturing industries in Singapore applied labour inputs differently in the early 1970s but similarly since the late 1980s. On the other hand, the applications of capital inputs were increasingly diverse after the mid-1980s.[52]

Table 4.6 Estimates of frontier and mean coefficients of production function for Singapore's manufacturing, 1970–1997

Year	Range of actual response coefficients								
	Minimal varying coefficients			*Frontier coefficients (maximal)*			*Mean coefficients*		
	Constant	Labour	Capital	Constant	Labour	Capital	Constant	Labour	Capital
1970	3.469	0.420	0.596	4.408	0.496	0.596	3.960	0.458	0.596
1971	4.173	0.493	0.529	5.364	0.507	0.529	4.726	0.500	0.529
1972	4.789	0.561	0.464	5.499	0.611	0.464	5.136	0.585	0.464
1973	4.795	0.537	0.478	5.234	0.537	0.518	5.008	0.537	0.498
1974	4.381	0.509	0.503	5.203	0.509	0.522	4.804	0.509	0.513
1975	3.809	0.490	0.532	5.217	0.490	0.532	4.565	0.490	0.532
1976	5.189	0.537	0.455	6.156	0.555	0.455	5.626	0.546	0.455
1977	4.764	0.397	0.542	5.476	0.455	0.542	5.125	0.429	0.542
1978	4.319	0.319	0.610	4.788	0.395	0.610	4.540	0.359	0.610
1979	3.708	0.244	0.680	4.452	0.294	0.680	4.099	0.271	0.680
1980	3.393	0.340	0.653	3.978	0.390	0.653	3.646	0.364	0.653
1981	3.418	0.325	0.644	4.118	0.407	0.644	3.771	0.369	0.644
1982	3.726	0.473	0.544	4.307	0.576	0.544	3.975	0.519	0.544
1983	3.540	0.366	0.617	3.791	0.482	0.617	3.649	0.418	0.617
1984	2.634	0.296	0.696	2.860	0.412	0.696	2.741	0.353	0.696
1985	1.605	0.335	0.728	2.235	0.387	0.735	1.912	0.361	0.732
1986	1.602	0.280	0.761	2.134	0.343	0.761	1.860	0.309	0.761
1987	2.032	0.278	0.746	2.585	0.318	0.753	2.319	0.298	0.750
1988	2.486	0.298	0.711	3.085	0.310	0.734	2.817	0.304	0.723
1989	3.078	0.328	0.674	3.600	0.341	0.691	3.316	0.335	0.682
1990	3.654	0.398	0.618	3.748	0.398	0.660	3.695	0.398	0.634
1991	2.205	0.339	0.716	3.084	0.339	0.716	2.591	0.339	0.716
1992	3.042	0.404	0.643	3.332	0.404	0.672	3.181	0.404	0.657
1993	2.595	0.388	0.670	2.906	0.388	0.703	2.755	0.388	0.686
1994	2.224	0.358	0.704	2.379	0.358	0.745	2.304	0.358	0.725
1995	2.811	0.415	0.649	3.069	0.415	0.686	2.923	0.415	0.665
1996	3.986	0.521	0.532	4.254	0.521	0.573	4.122	0.521	0.553
1997	4.215	0.534	0.515	4.503	0.534	0.555	4.360	0.534	0.536
Average	3.416	0.399	0.615	3.992	0.435	0.628	3.697	0.417	0.621

Notes and source: As in Table 4.3.

[52] As mentioned earlier, there were one or two industries removed temporarily for Singapore, this elucidates why inconsistency occurred in 1991 between Table 4.2 and Table 4.6. According to Table 4.6, no variations were found in estimated labour and capital coefficients but the heterogeneity of manufacturing industries was statistically significant in Singapore as shown in Table 4.2. This problem arose due to the temporary removal of an industry.

It is worth mentioning that the estimated mean labour coefficient fell sharply from 0.546 in 1976 to 0.271 in 1979. The falling labour share ($= MP_L * L/Y$) was attributable to the changes in marginal product of labour or labour-output ratio or both. Yet, further analysis cannot be implemented due to the focus of this study and the limited data set. Furthermore, the returns to scale on the basis of estimated frontier coefficients were between 0.974 in 1979 and 1.122 in 1985.

Table 4.7 Estimates of frontier and mean coefficients of production function for Taiwan's manufacturing, 1981–1999

Year	Range of actual response coefficients								
	Minimal varying coefficients			*Frontier coefficients (maximal)*			*Mean coefficients*		
	Constant	Labour	Capital	Constant	Labour	Capital	Constant	Labour	Capital
1981	1.737	0.577	0.368	2.573	0.577	0.395	2.131	0.577	0.380
1982	1.548	0.594	0.365	2.314	0.594	0.402	1.913	0.594	0.381
1983	1.699	0.547	0.411	2.509	0.547	0.444	2.074	0.547	0.425
1984	1.496	0.560	0.430	2.217	0.560	0.458	1.811	0.560	0.442
1985	1.295	0.540	0.477	2.065	0.540	0.494	1.591	0.540	0.484
1986	1.312	0.545	0.490	2.025	0.545	0.493	1.575	0.545	0.491
1987	1.022	0.574	0.488	1.808	0.574	0.488	1.308	0.574	0.488
1988	0.936	0.570	0.493	1.807	0.570	0.493	1.301	0.570	0.493
1989	0.633	0.605	0.486	1.449	0.605	0.486	0.957	0.605	0.486
1990	0.233	0.626	0.496	1.060	0.626	0.496	0.579	0.626	0.496
1991	–0.123	0.667	0.490	0.629	0.667	0.490	0.206	0.667	0.490
1992	–0.071	0.646	0.504	0.521	0.664	0.504	0.204	0.654	0.504
1993	0.650	0.608	0.529	0.960	0.658	0.529	0.822	0.635	0.529
1994	0.580	0.554	0.588	0.693	0.622	0.588	0.643	0.592	0.588
1995	0.240	0.579	0.592	0.386	0.645	0.592	0.319	0.615	0.592
1996	0.296	0.609	0.552	0.375	0.690	0.552	0.336	0.651	0.552
1997	0.326	0.584	0.573	0.610	0.652	0.573	0.465	0.618	0.573
1998	0.501	0.540	0.596	0.782	0.612	0.596	0.639	0.576	0.596
1999	0.530	0.501	0.629	0.883	0.574	0.629	0.685	0.535	0.629
Average	0.781	0.580	0.503	1.351	0.606	0.511	1.029	0.594	0.506

Notes and source: As in Table 4.3.

In contrast to Singapore, Taiwan's manufacturing industries utilised their capital inputs differently in the early 1980s but in a similar manner after the mid-1980s. The applications of labour inputs became diverse after 1992. Besides, there was little variation in capital and labour coefficients between 1987 and 1991. The returns to scale dependent on the estimated frontier coefficients were rising over time, from 0.972 in 1981 to 1.242 in 1996. It should be mentioned that several industries received negative intercepts in

1991 and 1992. As production function is taken in logarithmic form in the estimation, negative constant terms are caused by logarithmic transformation if the parameter is less than one. To ensure the convergence of the estimation and mean value of intercepts to be positive, manufacturing value added was scaled up by 'ln (2)' during the 1993–99 period. This also helps illustrate the sudden increase in intercepts since 1993. However, while calculating the components of output growth, augmented intercepts were scaled down by 'ln (2)' to restore the originals.

Finally, the average of labour and capital shares (coefficients) on the basis of estimated frontier and mean coefficients are compared with Young (1995). As the estimates of labour and capital shares at the manufacturing level are available only for Korea, Singapore and Taiwan in Young (1995), this comparison excludes Hong Kong and Japan. As shown in Table 4.8, except for the Korean manufacturing sector during the 1970–75 period, the average estimates of labour and capital shares, as indicated by the estimated frontier coefficients, are in general comparable with those of Young (1995). Additionally, it should again be stressed that the empirical model of this study does not impose the strict assumption of constant returns to scale as in Young (1995). The average returns to scale derived from the estimated frontier coefficients for Hong Kong, Japan, Korea, Singapore, and Taiwan's manufacturing sectors were 1.002, 1.00, 1.039, 1063, and 1.117, respectively.

Table 4.8 Comparison of the average labour and capital shares between Young (1995) and this study for Korea, Singapore and Taiwan's manufacturing sectors

		Young (1995)	Frontier coefficients (maximal)		Mean coefficients	
Country	Period	Labour share	Labour share	Capital share	Labour share	Capital share
Korea	1970–75	0.477	0.802	0.350	0.757	0.349
	1975–80	0.503	0.540	0.465	0.514	0.461
	1980–85	0.547	0.478	0.496	0.438	0.496
	1985–90	0.572	0.506	0.494	0.476	0.494
Singapore	1970–80	0.423	0.485	0.545	0.468	0.542
	1980–90	0.385	0.397	0.683	0.363	0.680
Taiwan	1970–80	0.566	NA	NA	NA	NA
	1980–90	0.613	0.568	0.461	0.568	0.452

Notes: 1. For Hong Kong, the labour shares at the manufacturing level are not available and Japan is not included in Young (1995). Young uses growth accounting with the assumption of constant returns to scale hence the capital shares can be simply obtained by one minus labour shares.
2. The calculation of the average frontier coefficients of labour and capital, e.g., for the period 1970–75, begins from 1970 and ends in 1974.
3. NA: not available.

4.4 Technical Efficiency in East Asian Manufacturing Industries

Whether manufacturing industries in East Asia have reached their output potential, i.e. utilising the given resources efficiently, is carefully examined using the concept of technical efficiency. The importance of this issue is evident. If actual output of manufacturing industries is found to be far away from output potential, this may stem from lack of a learning-by-doing effect due to poor management and coordination problems etc. In addition, introduction of up-to-date technology may initially contribute to the low level of technical efficiency.[53] According to the model, the potential (best practice) production frontier is constructed using the estimated frontier coefficients, described in Chapter 3. Then, the actual output of each industry is compared with the potential frontier output. In the context of the varying coefficients frontier model, technical efficiency is defined as 'actual output over potential output'. Given the same level of inputs, the closer to frontier output, the higher the level of technical efficiency, and vice versa.

Table 4.9 shows the technical efficiency of individual manufacturing industries in Hong Kong over the period 1976–97. The average technical efficiency of Hong Kong's manufacturing sector ranged from 51.6% in 1992 to 80.4% in 1979. Technical efficiency was relatively higher (over 65%) over the period 1978–84. Except for 1987, technical efficiency fell below 60% from 1985 to 1995. Recently, there was considerable improvement in technical efficiency from 52.5% in 1995 to 69.6% in 1997. In terms of individual industries, on average the beverages industry had the highest technical efficiency, followed by basic metals and chemical products. Interestingly, a number of industries also reached their potential at some stage, e.g., the wood industry in 1981, and the non-metal mineral industry in 1995.

Table 4.10 presents the technical efficiency of individual manufacturing industries in Japan over the period 1965–98. On average, the technical efficiency of Japan's manufacturing sector varied from 50.3% in 1987 to 62.6% in 1967. Unlike Hong Kong,

[53] In general, if a firm continues to update production technology without ever completely mastering the old technology, technical efficiency is unlikely to improve over time.

the variation of technical efficiency in Japan's manufacturing sector was comparatively small. Yet, looking at the development of technical efficiency in the past three decades, technical efficiency has gradually fallen since the early 1970s. This suggests that manufacturers in Japan did not apply the best practice technology efficiently because actual output was getting away from output potential.

Obviously, except for 1980 the chemicals (ISIC 352) industry always utilised labour and capital inputs efficiently. The second most efficient industry was petroleum refineries, followed by printing and publishing, and leather. On the other hand, the paper products, miscellaneous petroleum, and iron and steel industries were the least efficient industries over the sample period. As opposed to a small deterioration in technical efficiency for most industries, technical efficiency in the beverages industry increasingly improved.

Table 4.11 presents the technical efficiency of individual manufacturing industries in Korea over the period 1970–97. Unlike Hong Kong and Japan, technical efficiency in Korea improved from 44.1% in 1973 to 75.2% in 1995. More specifically, in the first phase (1970–85) technical efficiency was below 55% and fluctuated at around 50%. During the second phase (1986–90), technical efficiency increased to above 55% except for 1987 and in the third phase (since 1991) even exceeded 60%.

Analogous to Japan, the Korean chemicals industry was the most efficient industry in terms of applying the best practice technology and except for 1981, 1986, and 1995 has always reached output potential since 1976. The second most efficient industry was miscellaneous petroleum, which also achieved its full potential over the 1971–73 period, as well as in 1981 and 1986. Besides theses two industries, the industrial chemicals, leather, and printing and publishing industries reached potential in 1970, 1974 and 1995, respectively. Despite a substantial technical efficiency improvement in recent years, the pottery industry was the least efficient industry in the 1970s. Similarly, the textile industry in general experienced the lowest technical efficiency in the 1980s and 1990s.

Table 4.12 shows the technical efficiency of individual manufacturing industries in Singapore over the period 1970–97. Technical efficiency for Singapore's manufacturing sector varied significantly from 34.3% in 1988 to 66.1% in 1994. Regardless of the large fluctuation, Singapore's industries became more technically efficient in the 1990s. There were six industries at different stages achieving full efficiency, including beverages, iron and steel, and industrial chemicals. In addition to those industries, rubber, other non-metallic mineral, and non-electrical machinery occasionally reached full efficiency. Obviously, the beverages industry was the most efficient industry, followed by iron and steel. The three industries regarded as the least efficient in Singapore were textiles, plastic and other manufactured products. With regard to the fluctuation in technical efficiency, it remains unclear as to why technical efficiency fluctuated so drastically in several industries, such as non-electrical machinery, electrical machinery, other non-metallic mineral.

Table 4.13 shows the technical efficiency of individual manufacturing industries in Taiwan over the period 1981–99. The highest technical efficiency for Taiwan's manufacturing sector occurred in 1994 at 69.1% and the lowest in 1999 at 54.9%. Technical efficiency from 1981 to 1985 was below 60% but was above 60% between 1986 and 1998. More specifically, technical efficiency was at an all-time high during the 1991–95 period.

In terms of individual industries, the combined industry, food, beverages and tobacco, experienced full efficiency over the period 1981–93. Since then, full efficiency occurred in the chemical material industry during the 1994–95 period. Interestingly, from 1996 to 1999 the furniture industry utilised its inputs the most efficiently. Despite being the most efficient industry, technical efficiency in the food industry has dropped gradually since 1993. By contrast, technical efficiency improved in the furniture industry from about 40% in the early 1980s to 100% in 1999. Due to falling efficiency, the textiles industry experienced the lowest efficiency.

Table 4.9 Technical efficiency of individual industries in Hong Kong (percent)

Industries	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
311 Food products	58.2	69.7	72.9	67.5	70.9	80.4	71.2	81.9	62.6	57.5	62.2	60.4	63.1	57.6	61.7	51.6	51.5	49.4	51.4	77.8	75.2	58.2
313 Beverages	100	90.7	96.9	100	95.9	100	100	100	100	100	80.4	97.5	99.2	100	100	100	100	100	#	#	#	100
321 Textiles	39.8	57.3	65.6	53.9	53.6	49.9	51.8	62.7	49.6	51.3	60.8	49.6	47.1	36.7	37.1	39.1	38.1	37.5	34.7	45.1	48.3	39.8
322 Wearing apparel	66.0	76.8	88.6	80.4	72.8	67.3	54.5	65.0	54.2	47.9	59.9	43.5	48.8	33.7	35.2	31.4	32.6	30.2	27.1	41.1	41.8	66.0
323 Leather products	51.9	63.3	78.4	69.4	59.2	58.7	65.8	72.8	49.5	59.8	55.2	40.0	53.7	49.1	51.7	52.2	45.4	59.4	54.4	59.1	79.7	51.9
324 Footwear	48.8	63.6	78.0	91.8	69.8	65.1	63.2	74.0	69.6	61.9	47.1	37.8	56.1	30.2	34.6	27.4	#	#	#	#	#	48.8
331 Wood products	80.0	93.4	92.7	74.2	100	82.9	87.1	84.4	69.7	73.1	64.0	45.3	49.3	48.8	52.0	44.8	40.4	46.3	51.1	55.0	72.7	80.0
332 Furniture	59.2	75.6	92.3	76.3	82.8	76.3	66.9	70.9	63.9	59.7	59.3	40.7	56.2	49.6	56.7	44.3	34.5	27.9	33.9	61.5	50.9	59.2
341 Paper and products	49.1	67.3	75.6	70.5	66.7	66.5	67.4	74.8	58.6	65.5	57.0	46.6	46.4	45.7	52.8	51.3	53.6	46.8	45.2	55.9	61.9	49.1
342 Printing and publishing	55.4	66.5	80.2	71.0	84.9	75.2	64.1	81.1	67.6	54.4	63.9	60.1	59.3	55.3	53.5	54.8	58.4	57.4	42.1	64.8	65.3	55.4
351 +352 (Chemical prod.)	54.2	67.7	82.2	77.7	79.8	71.8	73.9	94.4	68.5	63.0	62.3	65.6	71.7	70.7	96.6	73.9	71.4	69.1	64.2	100	99.1	54.2
355 Rubber products	41.6	40.4	60.1	48.0	46.4	49.7	43.3	56.5	46.9	38.1	36.8	33.7	41.2	45.4	45.1	40.8	42.3	37.6	53.0	58.3	65.9	41.6
356 Plastic products	46.2	56.5	66.7	55.5	58.8	53.8	46.5	63.8	49.7	47.0	45.6	43.7	43.3	34.9	35.3	36.2	38.8	36.5	42.5	46.6	49.9	46.2
36 Non-metal mineral	48.2	73.8	75.8	69.2	76.0	54.3	58.5	57.9	50.6	55.2	66.4	52.9	75.1	72.9	78.3	60.6	73.5	75.1	100	42.4	98.7	48.2
371 +372 (Basic metals)	80.7	100	100	81.5	70.9	69.0	66.6	74.1	46.8	55.9	100	98.4	100	70.7	84.9	75.8	73.5	62.7	93.0	86.2	99.3	80.7
381 Fabricated metal prod.	52.6	68.8	82.8	69.1	65.0	57.0	51.9	61.4	49.8	47.2	54.9	48.2	48.1	38.9	42.5	41.0	45.8	46.2	40.9	49.6	57.1	52.6
382 Non-electrical mach.	45.4	65.1	73.3	70.4	89.5	82.5	87.3	93.0	62.5	60.8	59.6	56.1	59.9	59.1	62.0	57.9	53.7	53.4	54.0	76.0	74.3	45.4
383 Electric machinery	58.7	69.2	82.3	73.0	84.0	77.1	62.4	70.7	44.4	45.4	58.7	48.2	44.5	33.2	37.6	44.6	50.3	63.6	60.8	70.4	76.1	58.7
384 Transport equipment	71.3	63.8	81.8	69.5	73.5	80.6	57.6	80.7	63.4	61.7	63.9	59.8	81.1	69.6	76.1	66.7	67.0	59.6	57.7	71.5	81.1	71.3
385 Professional equipment	52.6	65.5	82.4	72.4	69.9	62.2	58.9	68.3	52.0	51.2	52.1	50.8	54.7	44.5	47.7	43.6	45.2	47.4	45.6	54.3	63.0	52.6
390 Other manufactured	61.8	75.2	79.9	74.5	78.0	74.0	67.1	87.8	67.5	63.8	72.9	52.4	59.0	45.3	49.8	45.0	46.5	46.0	40.9	55.4	61.7	61.8
Simple average	**58.2**	**70.0**	**80.4**	**72.2**	**73.7**	**69.2**	**65.1**	**75.1**	**59.4**	**58.1**	**61.1**	**53.9**	**59.9**	**52.0**	**56.7**	**51.6**	**53.1**	**52.6**	**52.2**	**61.6**	**69.6**	**58.2**

Notes: 1. # denotes the removal of industry in the estimation; see the Appendix in this chapter for details.
2. Non-metal mineral products (36) industry includes pottery, china, earthenware (361), glass and product (362), and other non-metallic mineral (369) industries.

Source: Author's calculation.

Technical efficiency of individual industries in Japan, (percent), continued

3-digit industries	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
311 Food products	62.0	57.3	54.6	52.3	48.9	49.4	51.5	55.4	52.0	57.3	58.0	55.7	56.1	51.2	51.7	51.5	52.9	51.8	48.5	49.9
313 Beverages	57.2	61.1	61.9	60.0	58.3	61.0	62.0	66.9	63.8	56.3	63.8	58.4	60.5	62.9	54.6	55.7	59.4	62.6	64.2	69.0
321 Textiles	50.8	46.6	47.3	45.0	43.3	44.2	42.8	44.4	49.3	44.4	41.3	42.9	40.0	38.0	41.0	40.9	41.1	40.1	37.2	39.0
322 Wearing apparel	57.0	57.4	58.9	57.8	54.3	52.8	50.4	51.5	55.6	54.4	48.9	48.4	44.8	42.1	47.1	48.5	49.4	47.4	43.4	45.5
323 Leather products	82.2	80.3	81.4	80.1	78.2	71.8	67.3	73.7	76.3	69.8	63.3	65.8	62.9	60.1	66.1	64.9	64.1	64.6	63.0	70.8
324 Footwear	59.9	61.5	65.3	61.3	59.6	66.7	55.9	64.1	68.9	70.0	55.0	67.4	60.2	58.8	66.6	62.3	58.7	60.8	55.9	60.5
331 Wood products	57.0	56.0	56.6	55.2	51.6	52.6	46.9	52.4	63.5	54.7	46.5	46.2	46.7	45.0	51.6	51.4	45.9	46.3	43.7	44.8
332 Furniture	60.9	61.5	63.8	61.8	57.1	57.1	54.3	57.1	61.5	60.8	53.2	51.6	50.9	49.8	56.3	57.0	53.4	55.1	52.2	55.1
341 Paper and product	56.8	54.6	50.5	50.4	47.3	49.8	45.0	46.0	49.4	57.9	44.8	44.5	42.9	40.1	39.8	39.5	39.2	39.1	38.9	42.5
342 Printing and publishing	73.2	75.5	75.3	74.0	70.7	68.9	66.4	69.3	69.2	72.6	74.5	72.2	70.0	68.1	72.0	75.6	78.0	76.5	70.6	72.0
351 Industrial chemicals	61.2	60.5	63.6	63.0	64.6	63.6	56.1	58.8	59.4	55.8	50.4	51.3	50.0	50.6	51.6	45.6	43.9	45.2	48.7	57.7
352 Other chemicals	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	97.4	100	100	100	100
353 Petroleum refineries	76.8	78.4	81.9	88.0	75.8	76.9	73.8	81.0	89.5	83.4	74.1	91.6	79.4	64.8	87.9	98.3	82.1	92.8	83.7	86.5
354 Miscellaneous petroleum	53.2	47.2	46.0	41.7	44.4	44.2	43.6	43.6	45.5	50.1	48.5	39.8	41.9	43.9	43.0	40.5	49.8	41.4	36.7	37.4
355 Rubber products	56.6	57.2	59.6	54.4	47.4	47.7	46.1	52.2	52.4	51.4	45.4	47.3	45.5	45.1	45.5	46.0	44.1	44.0	43.1	46.3
356 Plastic products	45.8	49.7	51.1	54.3	53.7	52.7	50.9	55.3	60.4	63.5	51.5	53.8	51.3	51.1	54.3	52.7	51.8	50.9	49.7	54.2
361 Pottery, china, earthenware	57.7	54.9	58.0	56.8	53.8	53.1	48.8	49.4	51.4	52.5	49.5	47.7	48.3	43.6	45.5	49.4	46.0	45.4	43.9	49.6
362 Glass and product	68.0	64.2	72.8	73.2	70.4	67.4	60.8	65.1	67.1	57.2	49.9	64.5	62.4	59.4	56.3	54.0	54.8	56.7	58.8	66.0
369 Other non-metallic mineral	47.1	48.7	47.8	50.4	48.1	48.1	45.8	50.1	54.2	55.6	48.7	46.0	46.0	48.3	50.4	50.0	51.0	48.1	45.8	48.1
371 Iron and steel	45.1	44.6	50.2	42.5	45.1	45.7	39.2	44.8	52.1	52.3	42.3	44.8	41.7	43.3	50.4	48.0	45.2	44.0	36.7	43.0
372 Non-ferrous metals	55.3	61.2	61.1	55.0	54.9	51.1	43.2	49.3	59.0	56.3	40.3	45.1	44.0	41.5	47.8	51.2	44.3	39.8	36.4	43.2
381 Fabricated metal products	64.6	61.6	63.2	65.5	66.7	66.2	60.8	57.4	59.1	64.5	55.5	53.6	54.9	53.7	55.8	57.4	58.8	56.6	51.4	53.5
382 Non-electrical machinery	60.6	57.3	64.5	69.3	68.4	69.2	63.1	60.2	61.2	70.4	63.0	59.7	58.7	54.4	58.6	63.0	66.2	64.4	56.6	59.6
383 Electric machinery	66.3	62.2	67.6	67.2	65.4	65.8	56.8	59.8	58.1	60.6	50.9	55.8	56.3	52.7	55.6	58.6	61.9	58.4	54.1	57.3
384 Transport equipment	70.8	63.1	63.2	64.0	55.8	56.9	53.8	56.5	55.7	53.9	54.9	57.1	57.7	49.5	48.3	49.2	53.7	50.0	48.1	48.0
385 Professional equipment	50.0	54.5	57.5	57.4	54.9	51.3	51.1	49.9	51.7	56.5	50.6	48.7	51.6	48.7	48.5	50.4	50.7	47.6	45.4	47.3
390 Other manufactured	64.3	63.7	65.1	64.4	61.6	59.4	54.2	55.3	59.1	57.6	55.1	56.3	56.3	50.5	54.8	55.9	58.0	57.9	56.4	61.9
Simple average	**61.5**	**60.8**	**62.6**	**61.7**	**59.3**	**59.0**	**55.2**	**58.1**	**60.9**	**60.7**	**54.8**	**56.2**	**54.9**	**52.5**	**55.6**	**56.1**	**55.7**	**55.1**	**52.3**	**55.9**

Table 4.10 Technical efficiency of individual 3-digit industries in Japan, (percent)

3-digit industries	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
311 Food products	47.4	46.8	45.9	43.9	42.6	41.1	45.6	50.5	52.4	48.3	44.4	43.2	40.8	42.8
313 Beverages	67.9	66.6	62.0	67.6	62.7	61.7	61.1	58.0	57.6	83.4	81.7	85.2	86.8	88.3
321 Textiles	37.6	35.7	35.6	35.8	34.7	33.4	36.4	38.4	37.1	36.2	33.5	33.3	33.2	44.1
322 Wearing apparel	42.8	41.4	41.5	41.6	40.8	38.3	45.3	47.8	48.5	42.6	38.9	38.4	36.9	38.7
323 Leather products	75.8	68.0	66.5	73.8	71.0	68.1	75.1	72.6	66.1	62.9	59.2	57.3	53.3	70.3
324 Footwear	61.9	57.5	57.4	59.8	59.9	61.0	64.0	62.2	59.5	66.6	66.4	64.4	64.7	60.0
331 Wood products	44.0	43.5	45.7	46.2	45.6	45.2	50.0	51.5	55.1	54.4	50.8	50.2	47.5	46.8
332 Furniture	54.9	51.7	52.5	56.6	57.5	54.8	59.2	57.9	55.9	60.0	56.4	56.5	54.9	53.6
341 Paper and product	40.6	41.3	40.4	41.1	41.0	39.8	39.7	39.1	40.1	41.6	40.6	41.8	41.4	42.2
342 Printing and publishing	68.4	66.3	63.6	63.1	62.2	60.0	63.7	65.5	66.2	64.0	61.8	62.9	61.5	62.5
351 Industrial chemicals	57.2	59.7	57.6	63.0	64.5	65.2	64.6	64.3	58.4	57.4	60.0	58.7	62.0	63.5
352 Other chemicals	100	100	100	100	100	100	100	100	100	100	100	100	100	100
353 Petroleum refineries	87.0	69.0	80.6	76.2	62.6	52.3	77.4	84.3	86.8	91.5	70.9	56.3	43.4	46.2
354 Miscellaneous petroleum	37.8	40.4	36.2	38.1	44.5	46.4	44.3	43.4	43.2	40.6	42.2	46.8	48.2	50.6
355 Rubber products	47.0	43.5	43.7	45.5	43.3	45.9	47.2	47.5	44.5	42.7	42.0	43.6	46.4	46.2
356 Plastic products	51.9	48.3	46.3	45.7	45.4	44.2	48.4	48.9	47.9	46.4	42.1	42.3	41.5	43.3
361 Pottery, china, earthenware	43.7	37.6	36.7	39.8	38.1	37.2	39.3	39.2	39.9	39.6	39.2	38.8	40.6	40.6
362 Glass and product	67.2	55.8	54.3	60.3	61.0	58.8	54.0	49.7	46.6	49.0	44.2	46.1	50.0	51.3
369 Other non-metallic mineral	47.3	47.8	48.1	50.4	49.7	50.3	54.2	55.4	55.6	55.3	51.2	51.5	49.7	48.8
371 Iron and steel	44.7	38.4	38.1	45.2	46.9	48.2	50.0	47.2	42.2	39.7	39.2	39.9	43.1	43.7
372 Non-ferrous metals	39.2	35.5	33.5	39.9	40.9	41.8	40.5	38.4	36.1	35.2	35.1	37.5	39.3	40.9
381 Fabricated metal products	54.1	51.7	50.5	52.0	51.6	52.2	58.6	60.3	58.6	58.4	54.2	54.9	51.1	52.1
382 Non-electrical machinery	57.3	53.3	48.4	51.4	53.3	54.8	59.1	56.5	52.5	55.2	52.3	54.7	52.1	54.4
383 Electric machinery	50.0	44.5	41.0	41.1	41.1	40.4	43.9	42.3	42.7	41.8	40.9	41.4	39.9	42.4
384 Transport equipment	49.1	43.9	42.2	41.7	43.8	45.8	45.8	46.4	45.2	44.9	44.0	47.3	46.6	49.4
385 Professional equipment	48.7	42.7	36.5	38.7	38.9	39.2	41.2	39.1	38.4	46.8	47.2	50.6	51.9	53.7
390 Other manufactured	59.8	54.8	53.6	53.6	54.1	54.9	61.5	63.8	62.6	60.0	54.7	54.0	53.2	52.1
Simple average	**54.9**	**51.3**	**50.3**	**52.3**	**51.8**	**51.1**	**54.4**	**54.5**	**53.3**	**54.2**	**51.6**	**51.8**	**51.1**	**52.9**

Source: See Table 4.9.

Table 4.11 Technical efficiency of individual industries in Korea, (percent), continued

3-digit industries	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
311 Food products	55.4	56.3	51.2	32.5	33.2	45.3	49.9	56.3	58.6	56.8	57.6	59.6	58.4	55.9	52.5	54.0	55.7	48.7	51.8	52.9
321 Textiles	23.3	20.9	25.7	27.3	25.6	28.4	29.5	28.3	34.9	36.9	35.0	38.8	32.2	33.2	36.0	39.8	43.8	40.6	41.9	37.0
322 Wearing apparel	34.3	37.1	40.8	35.1	40.7	36.4	39.7	43.4	47.2	50.7	53.9	61.4	49.8	49.1	54.3	55.4	58.4	54.0	57.5	55.5
323 Leather products	48.2	60.9	65.3	83.7	100	98.6	53.8	39.2	50.5	45.0	39.8	61.3	48.5	44.4	50.8	56.7	67.8	68.2	65.4	60.3
324 Footwear	55.6	44.6	38.7	32.9	51.4	42.5	45.5	50.4	43.2	41.6	38.7	42.0	44.5	47.6	50.0	52.8	56.5	50.7	56.2	53.8
331 Wood products	39.4	49.7	49.2	44.5	46.0	36.5	33.7	32.9	39.8	33.1	23.2	23.7	33.2	29.4	28.8	28.5	30.5	30.9	36.6	38.8
332 Furniture	35.3	37.8	46.7	25.0	43.2	35.4	47.5	50.1	66.9	57.4	40.7	41.7	42.8	47.0	51.9	52.2	51.0	48.7	58.8	61.0
341 Paper and products	54.7	50.5	51.6	49.6	55.0	42.2	44.4	46.6	46.8	44.8	43.4	48.1	45.2	50.6	51.5	52.1	57.5	54.2	56.3	51.7
342 Printing and publishing	50.9	57.4	51.9	31.1	54.1	50.2	45.3	52.7	56.8	63.9	59.9	60.4	65.6	71.0	72.9	68.0	69.5	67.5	72.1	72.7
351 Industrial chemicals	100	79.1	80.1	48.6	69.9	67.8	55.3	47.9	52.8	52.8	60.0	60.7	51.3	52.8	57.1	58.2	63.1	58.9	62.7	57.3
352 Other chemicals	93.9	98.2	97.8	68.6	98.5	98.8	100	100	100	100	100	97.2	100	100	100	99.7	96.6	100	100	100
354 Miscellaneous petroleum	65.3	98.7	100	100	75.7	69.3	57.3	51.5	47.8	76.9	83.1	98.1	91.5	81.6	84.5	95.7	99.4	84.9	84.4	81.0
355 Rubber products	38.1	36.1	36.2	27.1	35.6	33.4	37.1	37.7	39.9	49.6	42.2	38.8	32.2	32.0	38.2	43.9	47.7	44.0	47.3	42.5
356 Plastic products	65.2	59.2	96.8	62.7	56.7	30.3	33.9	38.3	45.3	60.6	48.2	49.4	42.5	47.5	57.8	56.1	55.8	51.6	58.6	52.0
361 Pottery, china, earthenware	17.1	15.2	19.0	16.4	19.5	18.8	22.0	27.8	31.3	39.7	38.3	40.9	35.6	38.2	40.2	41.1	44.0	42.2	42.0	42.5
362 Glass and products	73.7	55.1	56.4	35.2	64.5	68.0	59.2	59.5	57.4	55.2	48.0	44.2	39.9	40.9	48.0	50.6	55.1	43.9	47.3	44.2
369 Other non-metallic mineral	44.4	40.5	42.0	34.5	44.8	52.3	45.2	41.9	40.0	46.9	45.9	46.8	38.3	45.4	46.0	46.2	50.7	46.7	53.9	56.1
371 Iron and steel	61.5	60.3	63.6	65.3	78.0	58.7	47.7	36.5	45.3	51.4	37.3	50.7	51.2	42.5	46.2	47.6	53.4	53.0	51.6	52.2
372 Non-ferrous metals	44.6	49.5	41.5	41.8	55.6	43.6	43.6	44.8	46.4	42.0	49.9	39.7	33.5	38.9	41.2	42.3	49.7	51.8	58.3	52.6
381 Fabricated metal products	39.6	33.8	36.2	35.8	56.6	42.2	39.6	47.1	59.4	54.8	40.3	50.3	49.5	46.4	45.6	49.2	56.5	54.1	61.1	60.6
382 Non-electrical machinery	39.6	39.4	42.3	44.9	52.8	46.5	49.4	45.5	50.3	49.1	34.3	38.7	35.8	41.6	46.4	49.3	58.3	53.6	61.7	59.9
383 Electric machinery	48.4	43.8	46.7	44.2	58.7	47.3	40.1	43.7	48.4	47.4	42.8	49.9	47.8	54.6	62.3	58.4	64.1	55.9	59.3	55.2
384 Transport equipment	62.7	54.0	45.3	44.0	48.5	40.2	46.3	59.3	51.8	42.7	39.1	48.5	49.8	51.1	53.2	56.4	58.0	51.4	51.4	49.6
385 Professional equipment	41.1	34.0	52.4	43.5	49.1	57.3	59.0	43.1	42.9	48.0	47.4	42.9	42.2	38.7	49.8	49.8	58.6	55.2	63.9	59.0
390 Other manufactured	39.1	33.9	29.5	29.2	38.7	39.6	40.7	41.6	42.4	44.2	45.6	53.1	49.1	48.7	48.2	50.8	61.9	59.3	59.4	54.8
Simple average	**50.9**	**49.8**	**52.3**	**44.1**	**54.1**	**49.2**	**46.6**	**46.6**	**49.8**	**51.7**	**47.8**	**51.5**	**48.4**	**49.2**	**52.5**	**54.2**	**58.6**	**54.8**	**58.4**	**56.1**

Technical efficiency of individual 3-digit industries in Korea, (percent)

3-digit industries	1990	1991	1992	1993	1994	1995	1996	1997
311 Food products	57.6	63.3	72.5	65.2	65.6	70.9	69.8	66.2
321 Textiles	34.6	38.9	45.3	39.1	40.6	43.9	42.7	40.4
322 Wearing apparel	61.0	53.7	59.1	62.7	69.2	88.5	77.8	76.1
323 Leather products	70.6	67.1	83.5	73.1	84.6	83.3	79.9	73.5
324 Footwear	62.6	82.5	77.0	56.4	55.5	61.6	71.4	61.3
331 Wood products	45.3	58.4	59.2	58.0	60.9	71.5	67.0	67.0
332 Furniture	71.1	81.8	42.0	36.9	44.4	48.3	49.8	48.2
341 Paper and products	49.7	60.1	66.5	57.6	63.6	72.9	70.9	65.9
342 Printing and publishing	82.5	72.9	83.5	82.9	85.5	100	97.4	86.4
351 Industrial chemicals	62.0	69.1	70.2	63.1	63.1	80.7	97.8	93.8
352 Other chemicals	100	100	100	100	100	98.1	100	100
354 Miscellaneous petroleum	69.1	74.5	96.0	91.6	76.8	78.6	70.0	63.2
355 Rubber products	45.3	47.7	55.9	50.6	53.6	62.3	69.0	58.5
356 Plastic products	53.4	68.3	82.0	63.7	72.7	86.3	49.6	47.1
361 Pottery, china, earthenware	42.1	42.2	48.4	49.8	49.8	60.1	57.0	56.4
362 Glass and products	54.2	66.2	72.9	62.5	72.8	88.8	79.1	72.6
369 Other non-metallic mineral	59.9	74.3	72.2	63.2	62.0	72.3	72.2	68.3
371 Iron and steel	53.3	67.1	71.7	63.0	69.9	78.5	72.9	66.5
372 Non-ferrous metals	48.9	61.4	62.2	53.2	56.1	77.1	65.3	66.7
381 Fabricated metal products	64.8	59.6	66.5	59.9	68.5	70.4	72.5	64.1
382 Non-electrical machinery	65.5	71.0	70.7	61.0	63.9	73.4	73.5	70.6
383 Electric machinery	59.5	56.1	58.6	57.0	68.9	90.4	82.7	65.8
384 Transport equipment	59.6	64.5	69.8	57.2	61.7	65.9	63.8	65.5
385 Professional equipment	59.3	52.2	63.3	57.4	67.9	85.0	80.7	79.3
390 Other manufactured products	56.2	52.0	59.0	54.8	59.2	72.4	64.1	60.7
Simple average	**59.5**	**64.2**	**68.3**	**61.6**	**65.5**	**75.2**	**71.9**	**67.3**

Source: See Table 4.9.

Table 4.12 Technical efficiency of individual industries in Singapore, (percent), continued

Industries	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
311 Food products	42.1	52.5	56.7	48.6	35.8	60.5	58.6	66.5	60.7	53.7	42.0	54.1	40.2	49.8	50.8	45.7	41.3	32.8	26.5	43.2
313 Beverages	100	100	93.8	71.9	54.9	100	100	100	96.8	85.7	83.3	97.7	88.9	100	100	100	99.7	75.9	59.6	50.3
321 Textiles	21.8	26.8	33.2	34.1	18.0	24.4	32.1	29.7	31.0	33.7	30.1	26.4	21.4	28.8	29.8	30.5	39.1	34.7	25.0	32.6
322 Wearing apparel	31.7	34.8	38.3	28.1	21.4	32.3	38.8	45.2	53.0	54.5	44.6	44.3	34.6	45.0	56.3	40.1	35.2	33.7	26.4	50.3
323 Leather products	48.5	46.3	68.2	63.4	50.4	52.5	71.4	83.3	76.5	65.1	60.5	54.4	51.2	53.8	69.1	75.8	81.5	67.5	65.9	86.3
324 Footwear	39.9	50.2	51.0	30.8	25.6	50.8	43.6	36.3	41.1	45.7	35.8	33.6	26.8	37.0	41.3	37.0	37.1	30.6	23.7	36.7
331 Wood products	45.3	41.9	38.6	42.0	21.4	31.5	50.1	54.0	59.1	54.4	32.0	34.7	26.3	36.0	35.7	34.1	33.1	26.6	24.9	38.9
332 Furniture	60.9	58.2	59.2	48.8	26.7	44.9	48.6	48.6	49.4	41.8	41.6	45.6	37.1	46.1	57.7	49.7	40.8	27.3	23.0	39.9
341 Paper and products	34.6	40.2	50.7	47.1	32.2	42.3	44.7	48.0	49.3	53.4	53.4	42.6	32.6	45.4	51.0	60.9	59.2	48.5	33.8	45.8
342 Printing and publishing	42.8	44.0	60.8	45.9	40.0	63.8	62.6	69.0	67.8	59.8	50.8	57.6	45.0	59.3	61.6	51.3	42.7	34.7	27.1	46.0
351 Industrial chemicals	49.4	55.9	81.4	65.6	37.9	56.4	65.5	62.0	53.3	49.2	47.8	50.3	46.3	44.7	67.2	71.9	90.3	100	100	98.2
355 Rubber products	70.6	76.8	59.1	69.4	50.0	57.7	71.2	64.4	61.2	100	55.6	51.1	45.6	58.0	45.6	39.1	43.9	40.2	28.7	32.6
356 Plastic products	35.5	42.2	49.9	36.7	25.3	32.8	33.1	39.1	40.1	42.8	35.6	36.0	29.4	35.6	39.8	36.3	33.6	28.1	20.8	36.6
361 +362 Pottery, glass	29.4	29.1	35.5	31.1	25.6	46.8	49.9	59.9	72.6	62.6	39.0	37.1	30.5	43.1	46.9	35.1	28.7	24.7	18.5	31.4
369 Other non-metallic mineral	51.5	61.6	70.2	76.0	56.7	95.1	77.4	74.5	63.2	65.8	71.5	98.3	91.4	97.2	65.1	53.9	38.1	28.8	21.2	34.8
371 Iron and steel	81.7	60.5	97.9	100	100	72.0	71.9	79.9	100	93.6	100	98.9	100	92.4	72.9	67.0	84.5	73.2	55.7	68.1
372 Non-ferrous metals	72.6	66.9	42.8	38.0	29.0	49.0	46.1	49.6	47.3	56.7	53.3	69.1	52.1	73.3	87.3	84.9	93.6	73.3	59.5	59.6
381 Fabricated metal products	54.1	51.2	56.2	49.9	39.0	64.7	57.9	60.5	60.1	61.5	48.5	47.3	41.8	48.1	47.2	35.4	33.4	26.5	20.3	37.3
382 Non-electrical machinery	67.6	74.9	96.2	83.4	59.0	95.0	74.8	69.3	61.5	64.2	55.9	75.8	50.5	49.4	49.0	41.4	33.5	24.4	19.4	91.5
383 Electric machinery	76.9	68.7	75.7	60.5	47.4	70.1	68.3	71.7	72.4	77.6	56.2	48.5	33.8	46.4	62.2	41.1	35.6	29.3	19.4	26.8
384 Transport equipment	64.4	67.6	66.4	45.5	44.3	64.8	65.1	66.0	61.5	70.5	66.5	67.2	45.5	48.7	52.3	49.3	49.8	40.3	34.2	56.0
385 Professional equipment	23.5	35.1	45.6	25.1	17.1	35.3	32.2	29.1	35.3	30.1	28.9	24.2	24.3	29.4	39.7	50.9	53.2	39.4	29.9	44.1
390 Other manufactured products	24.6	29.6	32.6	26.4	24.4	38.4	42.8	44.0	51.0	59.1	50.1	46.4	31.3	41.8	40.2	41.1	43.8	38.2	24.7	30.8
Simple average	**50.9**	**52.8**	**59.1**	**50.8**	**38.3**	**55.7**	**56.8**	**58.7**	**59.3**	**60.1**	**51.4**	**54.0**	**44.6**	**52.6**	**55.2**	**51.0**	**50.9**	**42.6**	**34.3**	**48.6**

Technical efficiency of individual industries in Singapore, (percent)

Industries	1990	1991	1992	1993	1994	1995	1996	1997
311 Food products	49.0	56.8	57.9	52.6	54.6	49.5	61.8	59.1
313 Beverages	51.8	56.2	61.6	64.6	71.1	74.8	90.6	100
321 Textiles	40.2	45.5	47.9	47.1	51.8	44.0	42.3	48.1
322 Wearing apparel	40.4	46.7	54.4	49.2	48.5	38.5	35.3	35.1
323 Leather products	72.4	84.4	93.8	86.4	89.1	83.7	75.8	94.6
324 Footwear	43.0	46.5	52.8	61.6	65.9	63.0	74.7	62.6
331 Wood products	41.8	45.6	50.7	54.5	59.4	58.8	56.5	56.3
332 Furniture	38.2	47.7	61.2	63.4	62.2	58.5	55.7	50.4
341 Paper and products	60.5	66.6	63.5	63.5	63.1	57.9	62.4	58.7
342 Printing and publishing	52.5	61.5	73.0	71.5	75.4	70.1	71.3	71.9
351 Industrial chemicals	100	100	80.5	75.1	69.5	48.9	55.7	62.5
355 Rubber products	38.4	50.9	55.6	54.0	56.5	60.5	59.3	57.5
356 Plastic products	38.3	44.1	48.9	50.7	51.1	44.6	43.0	39.9
361 +362 Pottery, glass	28.3	35.6	48.1	48.2	53.7	63.3	52.6	51.7
369 Other non-metallic mineral	52.6	85.4	100	96.7	98.7	100	98.9	81.7
371 Iron and steel	70.8	76.0	84.4	56.6	49.2	50.2	52.7	59.1
372 Non-ferrous metals	84.1	84.5	96.5	89.6	83.5	49.5	55.0	49.4
381 Fabricated metal products	40.8	49.3	59.9	56.0	52.7	48.4	46.7	43.2
382 Non-electrical machinery	75.1	81.2	98.4	99.9	99.4	94.5	98.7	90.8
383 Electric machinery	29.9	35.2	44.1	43.9	47.5	48.9	46.3	42.5
384 Transport equipment	60.0	63.0	78.8	71.6	69.5	54.5	54.9	69.6
385 Professional equipment	46.9	51.3	65.0	71.5	73.9	72.7	79.8	81.2
390 Other manufactured products	34.9	40.6	42.3	39.0	39.1	40.4	37.7	43.8
Simple average	**51.7**	**58.9**	**66.1**	**63.8**	**64.6**	**59.8**	**61.2**	**61.3**

Source: See Table 4.9.

Table 4.13 Technical efficiency of individual industries in Taiwan, (percent)

Industries	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Food, beverages and tobacco	100	100	100	100	100	100	100	100	100	100	100	100	100	99.6	96.7	90.7	78.7	84.2	79.7
Textile mill products	49.3	45.3	41.5	43.4	41.9	49.3	46.0	41.8	44.2	43.7	47.8	45.3	42.5	42.2	39.9	36.4	34.6	33.8	29.1
Wearing apparel, accessories*	82.3	93.3	88.3	95.5	87.4	93.0	88.7	80.0	83.0	88.7	91.8	86.8	83.7	74.7	70.5	64.4	65.3	66.6	49.1
Leather, fur and products	65.5	69.7	63.7	69.3	71.8	77.8	66.8	62.0	62.2	64.5	69.7	58.1	59.6	63.2	57.8	54.5	47.2	45.2	40.3
Wood and bamboo products	33.1	32.2	32.0	37.5	43.1	55.0	56.6	50.2	48.9	45.0	54.5	60.3	68.2	63.8	61.4	57.6	58.0	56.0	49.2
Furniture and fixtures	46.5	40.3	39.8	43.1	40.7	50.5	50.5	54.6	60.8	59.0	68.2	75.5	82.6	92.3	97.5	100	100	100	100
Pulp, paper and paper products	70.2	65.2	59.3	63.8	61.8	71.0	67.4	60.4	58.9	54.3	51.4	45.5	42.0	41.8	41.9	37.4	35.2	34.1	32.0
Printing processings	76.2	63.8	57.5	61.3	55.2	59.7	54.5	54.6	53.0	53.8	53.1	54.8	55.6	55.1	53.8	46.7	45.9	52.8	47.5
Chemical material	52.9	56.4	57.0	67.0	67.4	78.2	73.8	72.9	75.2	79.0	88.5	90.2	94.8	100	100	97.9	91.4	88.7	76.5
Chemical products	34.3	37.2	36.2	42.5	45.6	53.4	52.4	50.0	46.6	49.5	53.5	56.3	62.6	65.6	69.5	70.7	73.5	75.3	69.7
Rubber products	48.4	51.7	49.6	48.3	49.4	51.5	50.7	50.8	50.0	56.6	60.8	64.6	65.8	65.4	64.4	56.4	48.2	45.9	41.7
Plastic products	33.3	33.8	34.0	36.0	38.0	47.2	45.5	46.6	45.7	45.0	47.1	45.7	48.4	49.4	46.2	45.6	43.8	39.4	36.4
Non-metallic mineral products	49.4	45.8	45.0	45.7	46.4	47.6	48.7	53.6	59.2	64.5	69.3	71.5	74.8	77.3	80.2	74.6	70.4	71.8	63.2
Basic metal industries	54.7	54.6	54.1	60.2	57.0	66.2	62.3	63.8	67.1	73.1	80.7	78.0	79.4	71.6	65.2	60.9	62.8	63.5	59.3
Fabricated metal products	50.4	44.2	44.0	46.5	46.9	52.3	48.3	50.3	50.2	50.5	55.7	54.6	52.5	53.1	52.2	44.3	42.1	42.1	41.0
Machinery and equipments	50.4	44.9	47.3	49.7	51.4	58.7	61.3	66.5	65.1	65.9	69.3	70.2	72.5	76.1	77.7	69.6	62.7	60.2	59.1
Electrical and electronic mach.	47.6	46.9	48.6	52.1	47.7	55.2	54.0	55.9	55.3	54.0	56.7	55.5	59.7	62.8	66.8	63.0	60.3	59.5	55.3
Transport equipments	80.0	80.6	74.4	74.6	65.3	71.8	78.0	77.1	87.4	87.9	92.0	92.0	86.7	82.0	78.6	64.9	59.2	59.8	50.2
Precision instruments	54.5	61.5	67.8	65.8	57.9	59.8	58.8	61.4	64.4	62.1	61.5	60.0	62.3	66.4	67.6	60.2	53.0	50.1	52.5
Other industrial products	75.0	71.5	73.4	77.5	75.2	82.1	80.0	82.2	78.0	73.7	72.4	73.8	77.5	79.3	82.3	80.5	77.5	72.8	66.4
Simple average	**57.7**	**56.9**	**55.7**	**59.0**	**57.5**	**64.0**	**62.2**	**61.7**	**62.8**	**63.5**	**67.2**	**66.9**	**68.6**	**69.1**	**68.5**	**63.8**	**60.5**	**60.1**	**54.9**

Source: See Table 4.9.

4.5 Appendix

4.5.1 Number of Industries and Sample Periods

The sample periods and number of industries examined in this study rest on the availability of data and the removal of some industries from the sample. Ideally, there are 28 industries at the 3-digit level for each country in the UNIDO database. In reality, the availability of data for each manufacturing sector varies from country to country. To be consistent, a number of specific adjustments have been made depending on the nature of individual manufacturing sectors. If the data for some 3-digit level industries are missing or unavailable, an alternative approach to maintain the maximum number of industries is to include industries at the 2-digit level. For instance, because the pottery, china and earthware (ISIC 361), glass products (ISIC 362), and other non-metal mineral products (ISIC 369) industries in Hong Kong exhibit a lot of missing data, the combination of these three industries, i.e., ISIC 36, is instead included in the sample. Such a rule also applies to Singapore. Occasionally, the use of interpolation is indispensable in order to reconstruct missing data.

Surprisingly, the estimation of frontier production function encounters difficulty if certain industries are included. Thus, another aspect that affects the number of industries covered in this study has to do with removal of some industries.

First of all, inclusion of the tobacco industry in general influences the outcome of estimation dramatically and even the convergence of estimation; for instance, due to divergence, it is difficult to obtain the frontier coefficients, namely, production frontier. Even if the estimated coefficients are obtained, the preliminary result has found that incorporation of the tobacco industry always pushes up the production frontier and leads to actual output of other industries significantly below the production frontier. For example, if the tobacco industry is included in the estimation for Hong Kong, it obtains full technical efficiency, namely, 100%, while the technical efficiency of other industries falls sharply to about 10% or even less. Without the tobacco industry, the average technical efficiency of other industries recovers to around 60%, which seems more reliable.

Second, other peculiar and insignificant results include technology regression across most industries and large swings in technical efficiency change and technological progress over time. Furthermore, the volatility of GFCF data in the tobacco industry in Hong Kong creates difficulty in estimating capital stock.[54] In order to obtain accurate estimation results, the tobacco industry is excluded from the sample except for Taiwan. Because the tobacco industry is combined with two other industries (food and beverages) as a single industry in Taiwan, the above problems do not appear.

Third, from the viewpoint of actual data, it is found that the output-capital and/or output-labour ratios of the tobacco industry are much higher than those of other industries. Put differently, the tobacco industry can produce a similar level of output to other industries but with far less inputs, and vice versa. On the whole, state-owned industries, such as tobacco and petroleum refineries, are most likely to exhibit this phenomenon because they normally operate as monopolies. As a result, their output (measured in value added) is usually overvalued because output prices are usually regulated by government. By chance, this view echoes Färe, Grosskopf and Lee (2001). While examining productivity growth in 16 Taiwanese manufacturing industries, they also exclude the beverages, tobacco, petroleum and coal industries. Because these two industries operate as near monopolies in Taiwan, their output values are unavoidably inflated by *monopoly profits* and *tax revenues* suggesting the exaggeration of relative productivity of monopolies. In addition, they observe that the inclusion of these two industries results in peculiar outcomes, i.e. technology regression.

Consequently, which industries should be removed in this study is based on the above explanation (or criterion). There is no doubt that the removal of industries cannot be simply resolved by looking at the figures of output-capital ratio against output-labour ratio. Examining the results of the estimated frontier coefficients, returns to scale, and convergence is another important criterion.

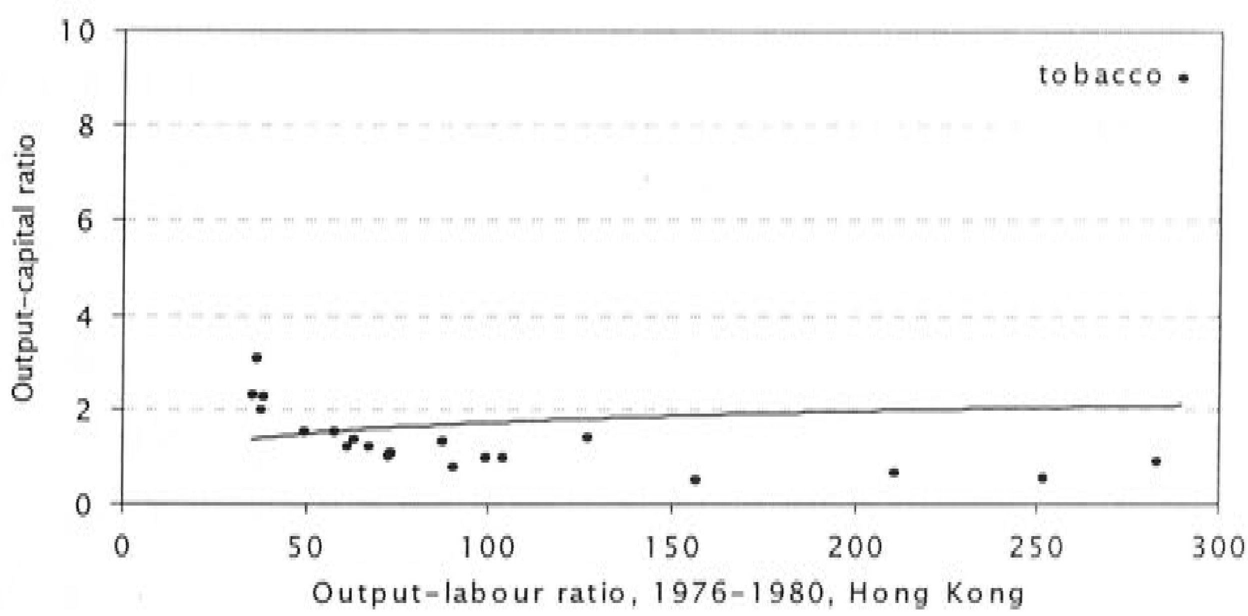
Due to the unavailability of firm-level data for the five East Asian manufacturing sectors, this study has no choice but to use the aggregate data at the 3-digit level and further assumes all manufacturing industries within each economy use more or less similar production technologies. Like all other methodologies, such limitations exist. One might suspect that the peculiar estimation results, if the tobacco industry or others are

[54] For instance, the real GFCF of the tobacco industry in 1987 was 65 times higher than in 1977 and the real GFCF in 1984 was at least 17 times larger than in 1983.

included, may be related to the assumption imposed by the varying coefficients frontier model. So, a possible criticism of the approach used in this study is that manufacturing industries within each economy may apply dissimilar production technology. Nonetheless, while analysing the sources of economic growth for the East Asian NICs, Kim and Lau (1994) also assume that the four East Asian NICs and a group of the five developed countries have the same meta-production function at the economy level. Moreover, it is worth mentioning that both studies have applied a micro concept approach to analyse a macroeconomic issue. The use of production function in numerous empirical aggregate and growth accounting studies has been frequently seen in the literature.

Finally, the speculation that some of the manufacturing industries, e.g. tobacco, utilise different types of frontier production technology may not be completely ruled out. This helps explain the earlier unsatisfactory outcomes, when the tobacco industry is included, and what has been happening in those output-capital and output-labour ratios. Yet, more empirical evidence and econometric hypothesis testing are required to examine this speculation.

Figure 4.17 Average output-capital ratio against average output-labour ratio in Hong Kong's manufacturing industries, 1976–80



Note: The unit of output-labour ratio is 'HK$ thousands/ person'.
Source: UNIDO database deflated at constant 1990 prices and author's calculation.

The evidence of irregular (or extreme) output-capital, output-labour or capital-labour ratios is presented in Figures 4.17 to Figure 4.21. Moreover, it should be noted that the output-labour ratio of Hong Kong in Figure 4.17 may not be comparable with those of other manufacturing sectors since manufacturing value added are measured in local currency and the periods covered are different.

The output-capital ratio against output-labour ratio in Hong Kong's manufacturing industries between 1976 and 1980 is shown in Figure 4.17. The distinctive industry marked in Figure 4.17 is the tobacco industry. Thus, the number of industries examined for Hong Kong between 1976 and 1992 is 21 due to the removal of the tobacco industry. Since 1993 the number of industries varies because of the removal of other industries. It is found that the footwear industry had an extremely low output-capital ratio from 1993, which was far below the average ratio. Therefore, it is temporarily deleted from the sample from 1993.[55] The beverages industry with negative capital stock in the period 1995–96 on account of the large negative GFCF is also removed from 1995 to 1997.[56] Overall, during the 1993–94 and 1995–97 periods, the numbers of industries covered in Hong Kong are reduced to 20 and 19, respectively.

The missing data for Hong Kong's manufacturing industries deserves some explanation. First, the data of petroleum refineries (ISIC 353) and miscellaneous petroleum and coal products (ISIC 354) in the UNIDO database show up as zero over the period 1976–87. Compared with other economies, Hong Kong is a service-oriented state; hence, it is conceivable Hong Kong may not have had those two heavy industries during that period. Or, such data are unavailable by all means in Hong Kong. Consequently, those two industries are excluded.

Second, the existing missing data and 'combined data' have brought about the combination of some 3-digit level industries to maintain a larger sample size.[57] In terms of missing data, the use of interpolation has reconstructed the data of manufacturing GFCF and value added for the pottery (ISIC 361) industry in 1992, 1993, and 1995 and the glass (ISIC 362) industry in 1994, and the data of manufacturing GFCF for the other non-metal mineral (ISIC 369) industry in 1992. As far as the combined data are

[55] Nevertheless, the analysis of output growth decomposition is still carried out for the footwear industry.
[56] The negative GFCF in the beverages industry may be due to the sale of capital stock or being transferred out of Hong Kong.
[57] The combined data means that the figures are only available at the 2-digit level, which has been confirmed by the *UNIDO Industrial Statistics Yearbook*.

concerned, the industrial chemicals and other chemicals industries are combined into a single chemical products (ISIC 351+352) industry. Three industries, pottery, glass and other non-metal mineral, are joined as a 2-digit level industry, non-metal mineral products (ISIC 36). The iron (ISIC 371) and steel and non-ferrous metals (ISIC 372) industries are combined into a 2-digit level industry, basic metals (ISIC 37). Most of the GFCF data of manufacturing industries are not available over the period 1974–75, so the construction of capital stock starts from 1976. Thus, the sample period for Hong Kong's manufacturing industries begins from 1976 to 1997.

For Japan, there are 27 industries during the 1963–84 period and 28 industries from 1985 onwards, because the data of value added and number of employees for the tobacco industry are available only after 1985. Accordingly, the tobacco industry is excluded and 27 manufacturing industries at the 3-digit level are included for Japan in this study.[58] The data of manufacturing value added and number of employees are available from 1963 to 1998 and data of GFCF from 1963 to 1997. Overall, Japan has retained the maximum number of industries and the sample period covers 1965 to 1998.

Corresponding to Japan, the data for Korea's manufacturing industries are well established apart from the combined data of manufacturing GFCF in 1991 and the data of manufacturing value added, number of employees, and GFCF in the period 1996–97 for the petroleum refineries (ISIC 353) and miscellaneous petroleum and coal products (ISIC 354) industries. Thus, it is assumed that the value of GFCF of 1991 in the petroleum and coal products industry is a simple average of 1990 and 1992. Then, the value of GFCF for the petroleum refineries industry can be obtained by subtracting the GFCF of the petroleum and coal products industry from the combined data.

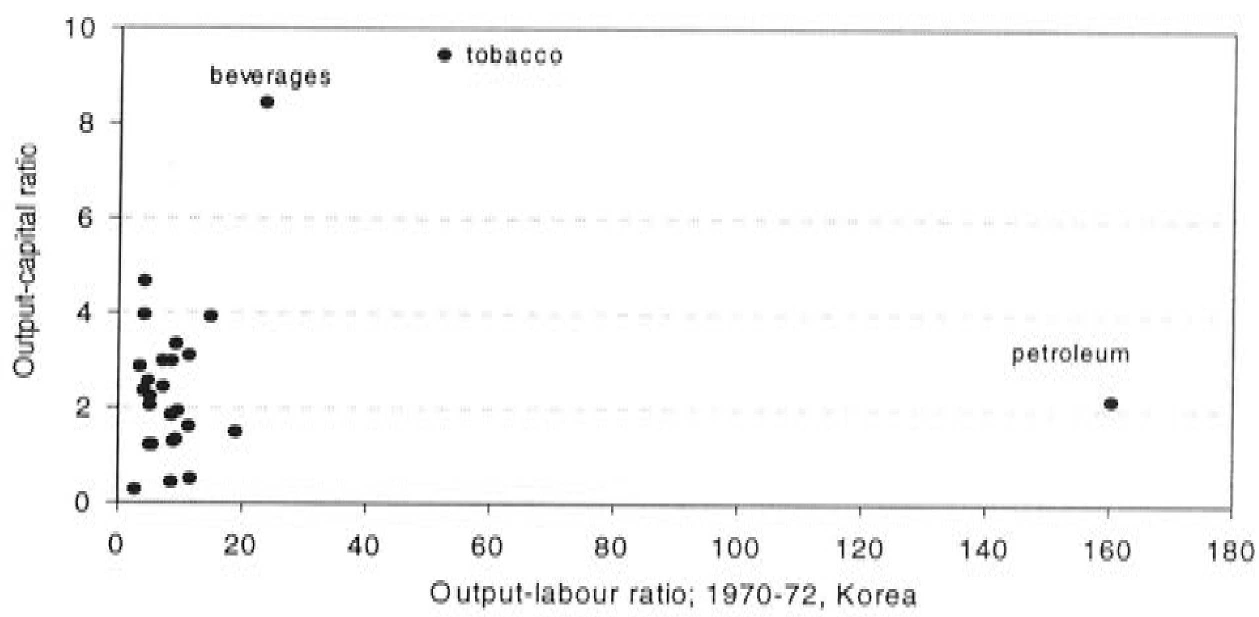
Figure 4.18 shows the output-capital ratio against output-labour ratio for Korean manufacturing industries between 1970 and 1972. Three industries marked in Figure 4.18 are the tobacco, petroleum refineries, and beverages industries. For similar reasons to Hong Kong, these three industries are excluded from the sample for Korea.[59] Despite the

[58] The attempt of incorporating the tobacco industry in the sample has failed due to the sudden change in the estimated intercept and frontier coefficients; that is, the estimated frontier coefficient of labour swings drastically, say, from 0.5 to 0.7.

[59] For instance, the output-labour ratio of the petroleum and coal products industry in 1995 was 271.4 while other industries on average had 28.1.

removal of these three industries, the remaining 25 industries accounted for over 93% of total manufacturing value added output in the 1990s. In spite of the availability of complete manufacturing GFCF data from 1967 to 1997 and manufacturing value added and number of employees from 1963 to 1997, the study for the Korean manufacturing sector covers the period 1970 to 1997 due to the unavailability of the deflators between 1967 and 1969.

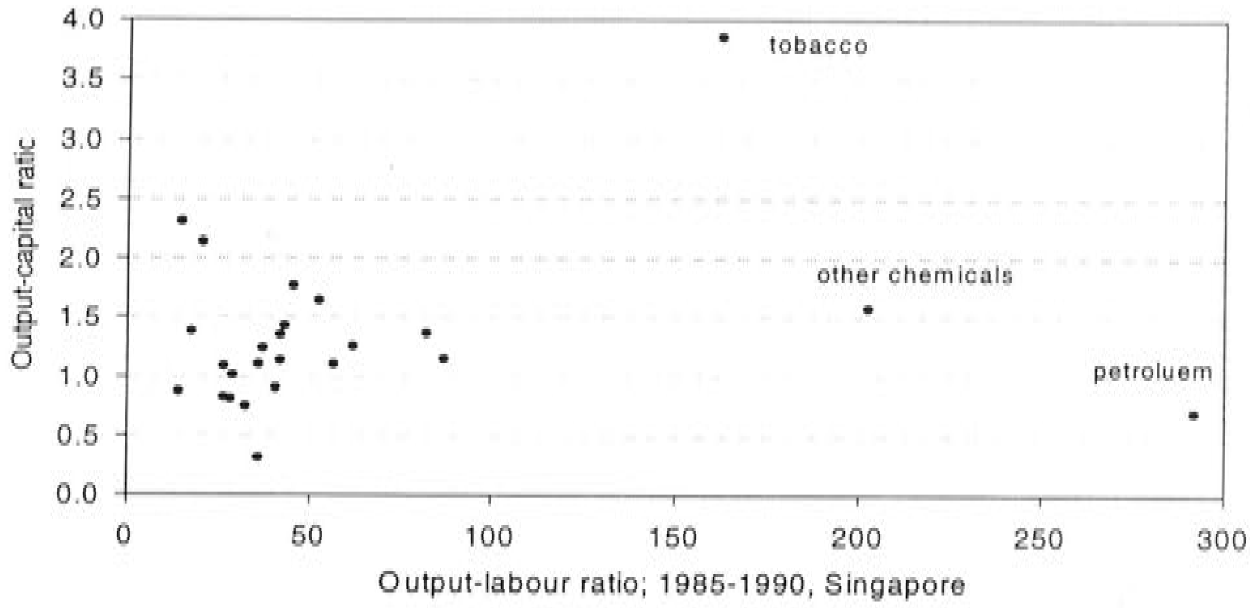
Figure 4.18 Average output-capital ratio against average output-labour ratio in Korea's manufacturing industries, 1970–1972



Note: The unit of output-labour ratio is 'Korean Won millions/ person'.
Source: As in Figure 4.17.

Due to the combined data for the petroleum refineries and petroleum and coal products industries in Singapore, these two industries have to be merged as a single industry (ISIC 353+354). As the data for the glass industry are available only from 1970 to 1974 and the data after 1974 is merged with the pottery industry, these two industries are joined as a single industry (ISIC 361+362). Figure 4.19 shows the output-capital ratio against output-labour ratio for Singapore's manufacturing industries during the period 1985–90. Similar to Hong Kong and Korea's manufacturing sectors, the three industries marked in Figure 4.19 and eliminated from the sample are tobacco, petroleum, and other chemicals industries. One of the three industries is easily detected at the outset but the other two are found in the late 1980s because the estimation of frontier coefficients becomes troublesome. Therefore, the number of industries examined for Singapore is 23 and the coverage of sample period is from 1970 to 1997.

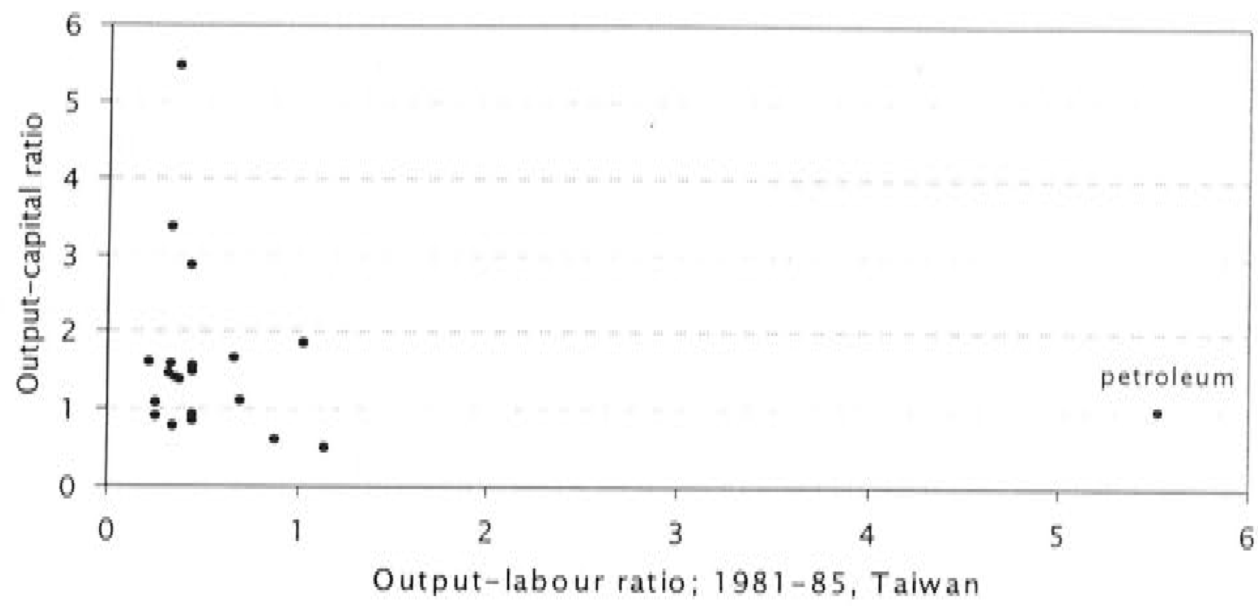
Figure 4.19 Average output-capital ratio against average output-labour ratio in Singapore's manufacturing industries, 1985–1990



Note: The unit of output-labour ratio is 'S$ thousands/ person'.
Source: As in Figure 4.17.

The sample period for Taiwan's manufacturing industries is from 1981 to 1999 due to the change of the industrial classification since 1981 and to lack of employment data (based on new industrial classification) before 1979. Despite the existence of manufacturing value added and GFCF data from 1966 and employment data from 1974 in the *Statistical Yearbook of the Republic of China* published by the DGBAS, the industrial classifications of these two separate data series differed between 1974 and 1980. Even though the employment data is available from the *Monthly Bulletin of Manpower Statistics* published by the DGBAS from 1979, the sample period cannot be extended to the period 1979–99 (two more years) because of the significant reduction in the number of industries. Also, Taiwan's manufacturing sector was divided into 17 industries before 1981 but into 22 industries after 1981 in the *National Income in Taiwan Area of the Republic of China*, published by the DGBAS. To maintain the maximum number of industries, the sample period is from 1981 to 1999.

Figure 4.20 Average output-capital ratio against average output-labour ratio in Taiwan's manufacturing industries, 1981–1985



Note: The unit of output-labour ratio is 'NT$ millions/ person'.
Source: As in Figure 4.17.

Figure 4.21 Average output-capital ratio against average output-labour ratio in Taiwan's manufacturing industries, 1981–1985

Note: The unit of output-labour ratio is 'NT$ millions/ person'.
Source: As in Figure 4.17.

Figures 4.20 and 4.21 present the detailed evidence of the output-labour ratio against output-capital and capital-labour ratios for Taiwan's manufacturing industries during the period 1981–85. The change of industrial classification in 1981 creates a difficulty for the beverages industry. The beverages industry together with tobacco was classified as a single industry before 1981 but was combined with the food industry after 1981. To overcome the problem, this study aggregates these three industries, food, beverages and tobacco, as a single industry. For similar reasons to those discussed earlier for Hong Kong, and Korea, this study excludes the petroleum and coal products industry as marked in Figures 4.20 and 4.21.[60] Thus, the number of industries studied for Taiwan is 20. In sum, the numbers of manufacturing industries and sample periods examined for the five East Asian manufacturing sectors are summarised in Table 4.14.

Finally, the initialisation of the capital stock of 1980 in Taiwan warrants an explanation. To retain the industries of 1981 in the sample, it is suggested that the data of GFCF of 1980 is required. Therefore, the extrapolation is required to generate the GFCF data of 1980 for five industries, precision, plastic products, chemical products, printing and furniture.

Table 4.14 The number of 3-digit manufacturing industries and time periods examined

Country	Period	No. of industries	Industries excluded
Hong Kong	1976–92	21	Tobacco
	1993–94	20	Tobacco, footwear
	1995–97	19	Tobacco, footwear, beverages[$]
Japan	1965–98	27	Tobacco[#]
Korea	1970–97	25	Tobacco, petroleum refineries, beverages
Singapore	1970–97	23	Tobacco, petroleum refineries & miscellaneous petroleum and coal products*, other chemicals
Taiwan	1981–99	20	Petroleum and coal products

[60] On average, the output-labour ratio of the petroleum and coal products industry was more than 10 times higher than other industries. If the petroleum and coal products industry is included, the returns to scale, dependent on estimated frontier coefficients, in the first three years will be very low between 0.82 and 0.87, which seems unreliable empirically. If the returns to scale are calculated based on the mean coefficients, they become even lower, say, less than 0.8. According to the empirical model outlined in Chapter 3, the returns to scale based on estimated frontier coefficients should be close to or slightly greater than one as estimated frontier coefficients are selected from the largest labour and capital coefficients among industries.

4.5.2 Varying Coefficients across Industries in Selected Years

This appendix presents the actual varying coefficients (intercepts and coefficients of labour and capital) across manufacturing industries. To conserve space, results will only be presented for two selected years. For Japan, Korea, Singapore, and Taiwan*, they are 1980 (1981*) and 1995, respectively. Due to the smaller sample size in 1995 in Hong Kong, they are 1980 and 1990, respectively.

Table 4.15 Estimates of intercept and coefficients of labour and capital for individual manufacturing industries in Hong Kong in 1980 and 1990

Industries	Constant	Labour	Capital	Constant	Labour	Capital
		1980			1990	
311 Food products	7.631	0.504	0.409	7.830	0.682	0.335
313 Beverages	**7.662**	**0.541**	**0.409**	**7.909**	**0.730**	**0.335**
321 Textiles	7.623	0.491	0.409	7.791	0.654	0.335
322 Wearing apparel	7.646	0.525	0.409	7.783	0.652	0.335
323 Leather products	7.631	0.503	0.409	7.783	0.655	0.335
324 Footwear	7.654	0.532	0.409	7.704	0.609	0.335
331 Wood products	7.639	0.510	0.409	7.783	0.655	0.335
332 Furniture	7.639	0.513	0.409	7.791	0.660	0.335
341 Paper and products	7.639	0.508	0.409	7.791	0.660	0.335
342 Printing and publishing	7.639	0.510	0.409	7.822	0.682	0.335
351 +352 (Chemical products)	7.639	0.515	0.409	7.854	0.698	0.335
355 Rubber products	7.600	0.462	0.409	7.743	0.638	0.335
356 Plastic products	7.623	0.492	0.409	7.775	0.644	0.335
36 Non-metal mineral products	7.631	0.501	0.409	7.854	0.698	0.335
371 +372 (Basic metals)	7.646	0.519	0.409	7.854	0.694	0.335
381 Fabricated metal products	7.639	0.511	0.409	7.783	0.653	0.335
382 Non-electrical machinery	7.639	0.509	0.409	7.830	0.688	0.335
383 Electric machinery	7.639	0.516	0.409	7.775	0.644	0.335
384 Transport equipment	7.639	0.507	0.409	7.854	0.698	0.335
385 Professional equipment	7.639	0.513	0.409	7.799	0.663	0.335
390 Other manufactured products	7.639	0.515	0.409	7.799	0.663	0.335

Notes: 1. In 1995, the number of manufacturing industries reduces to 19 as seen in Table 3.2. Instead of showing 1995's result, 1990's is presented here.
2. The figures in bold denote the frontier coefficients.

Source: Author's calculation using the computer program *TERAN*.

Table 4.16 Estimates of intercept and coefficients of labour and capital for individual manufacturing industries in Japan in 1980 and 1995

Industries	Constant	Labour	Capital	Constant	Labour	Capital
		1980			1995	
311 Food products	9.316	0.472	0.468	9.577	0.512	0.445
313 Beverages	9.316	0.473	0.468	9.764	0.539	0.445
321 Textiles	9.230	0.461	0.468	9.469	0.496	0.445
322 Wearing apparel	9.278	0.468	0.468	9.518	0.502	0.445
323 Leather products	9.373	0.479	0.468	9.636	0.520	0.445
324 Footwear	9.354	0.477	0.468	9.685	0.527	0.445
331 Wood products	9.306	0.471	0.468	9.597	0.515	0.445
332 Furniture	9.335	0.475	0.468	9.626	0.520	0.445
341 Paper and products	9.201	0.457	0.468	9.518	0.504	0.445
342 Printing and publishing	9.440	0.490	0.468	9.666	0.527	0.445
351 Industrial chemicals	9.249	0.464	0.468	9.656	0.523	0.445
352 Other chemicals	9.536	**0.502**	**0.468**	**9.833**	**0.551**	**0.445**
353 Petroleum refineries	**9.565**	0.500	0.468	9.715	0.529	0.445
354 Miscellaneous petroleum	9.134	0.454	0.468	9.459	0.499	0.445
355 Rubber products	9.239	0.464	0.468	9.518	0.504	0.445
356 Plastic products	9.306	0.472	0.468	9.548	0.507	0.445
361 Pottery, china, earthenware	9.259	0.466	0.468	9.479	0.499	0.445
362 Glass and products	9.297	0.471	0.468	9.518	0.505	0.445
369 Other non-metallic mineral	9.287	0.469	0.468	9.607	0.516	0.445
371 Iron and steel	9.278	0.468	0.468	9.508	0.502	0.445
372 Non-ferrous metals	9.287	0.469	0.468	9.449	0.494	0.445
381 Fabricated metal products	9.345	0.477	0.468	9.636	0.521	0.445
382 Non-electrical machinery	9.383	0.482	0.468	9.626	0.520	0.445
383 Electric machinery	9.354	0.479	0.468	9.557	0.508	0.445
384 Transport equipment	9.297	0.470	0.468	9.567	0.510	0.445
385 Professional equipment	9.287	0.469	0.468	9.577	0.512	0.445
390 Other manufactured products	9.326	0.474	0.468	9.626	0.519	0.445

Note: The figures in bold denote the frontier coefficients.
Source: See Table 4.15.

Table 4.17 Estimates of intercept and coefficients of labour and capital for individual manufacturing industries in Korea in 1980 and 1995 (continued)

Industries	Constant	Labour	Capital	Constant	Labour	Capital
		1980			1995	
311 Food products	8.646	0.389	0.523	7.969	0.610	0.475
321 Textiles	8.585	0.358	0.523	7.716	0.610	0.467
322 Wearing apparel	8.637	0.385	0.523	8.091	0.610	0.478
323 Leather products	8.567	0.353	0.523	8.050	0.610	0.477
324 Footwear	8.567	0.351	0.523	7.879	0.610	0.473
331 Wood products	8.489	0.316	0.523	7.969	0.610	0.475
332 Furniture	8.567	0.354	0.523	7.757	0.610	0.469
341 Paper and products	8.593	0.364	0.523	7.985	0.610	0.476
342 Printing and publishing	8.646	0.388	0.523	**8.156**	**0.610**	**0.480**

351 Industrial chemicals	8.646	0.388	0.523	8.042	0.610	0.477
352 Other chemicals	**8.733**	**0.428**	**0.523**	8.140	0.610	0.480
354 Miscellaneous petroleum	8.707	0.411	0.523	8.018	0.610	0.477
355 Rubber products	8.602	0.365	0.523	7.895	0.610	0.473
356 Plastic products	8.611	0.372	0.523	8.075	0.610	0.478
361 Pottery, china, earthenware	8.559	0.348	0.523	7.863	0.610	0.472
362 Glass and products	8.602	0.367	0.523	8.091	0.610	0.478
369 Other non-metallic mineral	8.611	0.369	0.523	7.977	0.610	0.476
371 Iron and steel	8.576	0.354	0.523	8.026	0.610	0.477
372 Non-ferrous metals	8.611	0.371	0.523	8.010	0.610	0.477
381 Fabricated metal products	8.593	0.361	0.523	7.961	0.610	0.475
382 Non-electrical machinery	8.567	0.349	0.523	7.985	0.610	0.476
383 Electric machinery	8.611	0.370	0.523	8.099	0.610	0.479
384 Transport equipment	8.593	0.360	0.523	7.936	0.610	0.474
385 Professional equipment	8.602	0.369	0.523	8.067	0.610	0.478
390 Other manufactured products	8.611	0.369	0.523	7.977	0.610	0.475

Note: The figures in bold denote the frontier coefficients.
Source: See Table 4.15.

Table 4.18 Estimates of intercept and coefficients of labour and capital for individual manufacturing industries in Singapore in 1980 and 1995

Industries	Constant	Labour	Capital	Constant	Labour	Capital
		1980			1995	
311 Food products	3.424	0.303	0.689	2.888	0.415	0.660
313 Beverages	3.739	0.341	0.689	2.992	0.415	0.675
321 Textiles	3.275	0.283	0.689	2.839	0.415	0.653
322 Wearing apparel	3.470	0.309	0.689	2.811	0.415	0.649
323 Leather products	3.566	0.320	0.689	3.026	0.415	0.677
324 Footwear	3.278	0.289	0.689	2.928	0.415	0.666
331 Wood products	3.305	0.287	0.689	2.919	0.415	0.664
332 Furniture	3.405	0.302	0.689	2.922	0.415	0.665
341 Paper and products	3.517	0.316	0.689	2.925	0.415	0.665
342 Printing and publishing	3.509	0.315	0.689	2.974	0.415	0.673
351 Industrial chemicals	3.447	0.307	0.689	2.888	0.415	0.660
355 Rubber products	3.536	0.318	0.689	2.928	0.415	0.666
356 Plastic products	3.351	0.294	0.689	2.863	0.415	0.656
361 +362 Pottery, Glass and product	3.302	0.293	0.689	2.946	0.415	0.668
369 Other non-metallic mineral	3.659	0.333	0.689	**3.069**	**0.415**	**0.686**
371 Iron and steel	**3.839**	**0.352**	**0.689**	2.882	0.415	0.660
372 Non-ferrous metals	3.467	0.310	0.689	2.866	0.415	0.658
381 Fabricated metal products	3.497	0.314	0.689	2.891	0.415	0.660
382 Non-electrical machinery	3.555	0.322	0.689	3.044	0.415	0.684
383 Electric machinery	3.566	0.325	0.689	2.900	0.415	0.662
384 Transport equipment	3.624	0.333	0.689	2.916	0.415	0.664
385 Professional equipment	3.263	0.281	0.689	2.983	0.415	0.674
390 Other manufactured products	3.497	0.313	0.689	2.824	0.415	0.651

Note: The figures in bold denote the frontier coefficients.
Source: See Table 4.15.

Table 4.19 Estimates of intercept and coefficients of labour and capital for individual manufacturing industries in Taiwan in 1981 and 1995

Industries	Constant	Labour	Capital	Constant	Labour	Capital
		1981			1995	
Food, beverages and tobacco	**2.573**	**0.577**	**0.395**	0.377	0.643	0.592
Textile mill products	2.066	0.577	0.378	0.246	0.580	0.592
Wearing apparel, accessories*	2.437	0.577	0.389	0.329	0.619	0.592
Leather, fur and products	2.249	0.577	0.383	0.289	0.602	0.592
Wood and bamboo products	1.737	0.577	0.368	0.298	0.607	0.592
Furniture and fixtures	1.974	0.577	0.376	0.383	0.643	0.592
Pulp, paper and paper products	2.316	0.577	0.386	0.240	0.579	0.592
Printing processings	2.375	0.577	0.387	0.280	0.597	0.592
Chemical material	2.120	0.577	0.380	**0.386**	**0.645**	**0.592**
Chemical products	1.755	0.577	0.369	0.325	0.617	0.592
Rubber products	2.017	0.577	0.377	0.309	0.610	0.592
Plastic products	1.770	0.577	0.368	0.269	0.591	0.592
Non-metallic mineral products	2.058	0.577	0.378	0.349	0.628	0.592
Basic metal industries	2.141	0.577	0.380	0.317	0.614	0.592
Fabricated metal products	2.064	0.577	0.378	0.289	0.600	0.592
Machinery and equipments	2.061	0.577	0.378	0.344	0.627	0.592
Electrical and electronic machinery	2.035	0.577	0.377	0.326	0.619	0.592
Transport equipments	2.411	0.577	0.389	0.346	0.628	0.592
Precision instruments	2.105	0.577	0.380	0.317	0.614	0.592
Other industrial products	2.365	0.577	0.387	0.353	0.630	0.592

Notes: 1. The sample period for Taiwan starts from 1981.
2. The figures in bold denote the frontier coefficients.

Source: See Table 4.15.

4.5.3 The Output of the Computer Program TERAN

An example of the empirical output generated by the computer program *TERAN* for Japan in 1980 is shown below. The results here correspond to Table 4.16.

```
technical efficiency estimates for the individual period  1

the ols estimates are :

                          coefficient   standard-error         t-ratio

 intercept             .93495327E+01    .90673422E+00    .10311216E+02
 x 1                   .47571898E+00    .49527078E-01    .96052302E+01
 x 2                   .46577218E+00    .41939700E-01    .11105758E+02
 sigma-squared         .52297198E-01

 breusch-pagan chi-squared value       .79806940E+01
               with degree of    2

the variance coefficient estimates are :

                          coefficient   standard-error         t-ratio

 intercept             .25172371E-01    .23045379E-01    .10922958E+01
 x 1                   .26709587E-03    .10306175E-03    .25916100E+01
 x 2                   .00000000E+00    .38425552E-04    .00000000E+00
 sigma-squared         .59701253E-02

the final wls estimates are :

                          coefficient   standard-error         t-ratio

 intercept             .93177261E+01    .22537865E+00    .41342542E+02
 x 1                   .47316646E+00    .12177618E-01    .38855419E+02
 x 2                   .46804184E+00    .10327099E-01    .45321714E+02
 sigma-squared         .52304607E-01

the frontier coefficients are :

 intercept             .95646585E+01
 x 1                   .50197013E+00
 x 2                   .46804184E+00

number of firms =   27

number of periods =    1

total number of observations =   27


technical efficiency estimates :

input specific technique efficiencies for period 2
firm no.,   intercept,   x1,   x2,   ...
   1          .974        .941      1.000
   2          .974        .942      1.000
   3          .965        .918      1.000
```

4	.970	.933	1.000
5	.980	.955	1.000
6	.978	.950	1.000
7	.973	.938	1.000
8	.976	.946	1.000
9	.962	.911	1.000
10	.987	.977	1.000
11	.967	.924	1.000
12	.997	1.000	1.000
13	1.000	.997	1.000
14	.955	.904	1.000
15	.966	.924	1.000
16	.973	.940	1.000
17	.968	.929	1.000
18	.972	.938	1.000
19	.971	.935	1.000
20	.970	.932	1.000
21	.971	.935	1.000
22	.977	.951	1.000
23	.981	.961	1.000
24	.978	.954	1.000
25	.972	.936	1.000
26	.971	.935	1.000
27	.975	.945	1.000

firm-no.	tech.-eff.%	allo.-eff%	econ.-eff.%
1	.51502932E+02		
2	.55732729E+02		
3	.40914759E+02		
4	.48486901E+02		
5	.64930283E+02		
6	.62315566E+02		
7	.51363269E+02		
8	.57019292E+02		
9	.39467765E+02		
10	.75587229E+02		
11	.45586140E+02		
12	.97409314E+02		
13	.98295330E+02		
14	.40461676E+02		
15	.45981857E+02		
16	.52665318E+02		
17	.49358959E+02		
18	.54026632E+02		
19	.50032358E+02		
20	.48021707E+02		
21	.51201708E+02		
22	.57433109E+02		
23	.63044901E+02		
24	.58647571E+02		
25	.49199812E+02		
26	.50433723E+02		
27	.55921286E+02		

mean technical eff. = .56112671E+02%

negative values are excluded in calculating mean effs.

Chapter 5

5 Sources of Output Growth

The use of the varying coefficients frontier model is strengthened by the Breusch-Pagan LM test discussed in Chapter 4. Therefore, the main objective of this chapter is to identify the sources of output growth and analyse the importance of TFP growth in different stages of economic growth in the East Asian manufacturing sectors. Section 5.1 decomposes output growth into input growth and TFP growth on the basis of a five-year period for individual manufacturing industries. The average share of industries in the manufacturing sector is briefly discussed prior to presenting the decomposition results of long-term output growth in section 5.2. The estimates and trends of annual TFP growth for the five manufacturing sectors are shown in section 5.3, and the detailed annual TFP growth estimates for individual manufacturing industries presented in Tables 5.18 to 5.22. As for decomposition of TFP growth and comparisons with earlier TFP studies, these are discussed next in Chapter 6.

It should be noted that TFP growth rates at the manufacturing level throughout this study are derived by summing up the contributions of individual industry estimated TFP growth to the entire manufacturing sector, that is, the TFP growth estimate for the manufacturing sector is a *weighted* average.[61] Taking the TFP growth of individual industries multiplied by the average shares of individual industries over the end-points, say, 1970 and 1975, and summing up all TFP growth contributions of individual industries can obtain the weighted TFP growth for the manufacturing sector over a five-year period. For instance, if the textiles industry has 10% TFP growth over the period

[61] As the weighted TFP growth also contains (or reveals) additional TFP growth due to shifts of labour and capital inputs from lower productivity industries to higher productivity industries, it differs for two reasons from the simple TFP growth estimate using the aggregate manufacturing data. First, the simple TFP growth estimates are in general misleading in the context of the current study because they do not take account of the industry-specific characteristics and interactions between industries. Second, the potential production frontier is generated for the manufacturing industries at the 3-digit level *not* the manufacturing level. Hence, this study derives the weighted TFP growth for the manufacturing sectors. In addition, this procedure applies to the calculation of input growth, technical efficiency change and technological progress.

1970–75 and 8% and 4% shares in the overall manufacturing sector in 1970 and 1975, respectively, the textiles industry contributes 0.6% TFP growth to final weighted TFP growth for the manufacturing sector. Instead of presenting the outcomes for individual manufacturing industries, unless otherwise indicated the discussion in general focuses on the entire manufacturing sector. Due to rounding, the figures may not add up in the following discussion.

5.1 DECOMPOSITION OF OUTPUT GROWTH: FIVE-YEAR SPAN

To conserve space, the decomposition of output growth in this section centres on a five-year span and the detailed decomposition of output growth into input growth and TFP growth is presented in Tables 5.1 to 5.5. As several industries are not included in the estimation, the weighted TFP growth and output growth for the manufacturing sectors do not comprise those removed industries. Thus, the weighted output growth rate in this study may be slightly different from those in official publications. The technical efficiency change and technological progress of individual industries over a five-year span are obtained using the frontier coefficients at the end-points, say 1970 and 1975 and inputs and output data.

5.1.1 Hong Kong

Table 5.1 shows the decomposition of output growth into input growth and TFP growth for manufacturing industries in Hong Kong over the 1976–97 period. Output growth over the period 1976–80 was positive across industries with the exception of the rubber industry (–3.7%). Similarly, only two industries, textiles and rubber, experienced negative input growth during this period. Despite five industries having negative TFP growth, the TFP growth for the entire manufacturing sector remained promising and, in particular, the non-metal mineral industry experienced the highest average annual TFP growth of 12.8%, followed by footwear with 9.8%. On average, the annual output growth rate for the entire manufacturing sector was 8.2%, stemming from 3.8% TFP growth and 4.5% input growth.

Due to 12 out of 21 industries experiencing negative output growth between 1980 and 1985, the average annual output growth of the manufacturing sector fell sharply from 8.2% to –1.0%. The worst result of –10.5% occurred in the basic metals industry; in contrast, the beverages industry had the highest average annual output growth rate of 6.0%. On average, input growth grew by only 0.3% a year and TFP growth fell sharply from 3.8% to –1.3%. Over the 1985–90 period, 6 out of 21 industries underwent negative output growth, with the footwear industry recording the worst average annual output growth of –19.6%. Nevertheless, the highest average annual output growth recorded of 22.3% was in the non-electrical machinery industry. The output growth rate for the manufacturing sector remained positive at 3.8% a year along with 4.1% annual TFP growth, indicating that annual input growth of –0.3% played no role over this period.

Over the period 1990–95, output growth and input growth declined sharply by 8.8% and 12.5% a year, respectively. Yet, average annual TFP growth was maintained at a similar rate of 3.8% compared with the previous period. As discussed in Chapter 2, the fall in output growth was due mainly to a rapid reallocation of manufacturing industries to mainland China since the mid-1980s. In the recent period of 1995–97, output growth and input growth did not improve. Despite the negative annual output growth of 4.8%, input growth fell even more by 8.3% a year, suggesting an average annual TFP growth rate of 3.6% for the manufacturing sector.

5.1.2 Japan

Table 5.2 presents the decomposition of output growth into input growth and TFP growth for manufacturing industries at the 3-digit level in Japan over the period 1965–98. Over the 1965–70 period, the Japanese manufacturing sector made a significant TFP progress at an annual rate of 6.6%. With this impressive TFP growth together with substantial input growth of 6.1%, manufacturing output grew remarkably by 12.7% a year. Besides that, all industries gained positive output, input and TFP growth.

In spite of 3.5% annual input growth, the average annual output growth over the 1970–75 period reduced to 3.7%, suggesting it was predominantly input-driven. In the wake of the oil crises in the early 1970s, TFP growth for the entire manufacturing sector only increased by 0.2% a year. Output growth during the 1975–80 period recovered to 6.2% a year but zero input growth implied substantial average annual TFP growth of 6.2%. In contrast to the first half of the 1970s, manufacturing output growth was completely driven by TFP growth.

Notwithstanding the sharp slowdown of annual TFP growth to 1.7% over the period 1980–85, manufacturing output still grew by 3.8% a year, due partly to 2.1% annual input growth. Similarly, between 1985 and 1990 average annual output, input and TFP growth improved slightly to 5.2%, 3.0%, and 2.2%, respectively. The decomposition of output growth in the 1980s suggests input growth and TFP growth were both critical to the output growth of the manufacturing sector.

During the first half of the 1990s and unprecedented in post-war Japan, output growth for the entire manufacturing sector declined by 0.8% a year due to the domestic economic downturn. The average annual input growth of 1.3% with negative output growth implicitly indicates that TFP growth fell by 2.2% per annum. During the 1995–98 period, manufacturing average annual output growth recovered slightly to 1.8%, which was mostly attributed to annual TFP growth of 1.5% because there was little input growth, only 0.2% a year.

5.1.3 Korea

Table 5.3 exhibits the decomposition of output growth into input growth and TFP growth for manufacturing industries at the 3-digit level in Korea over the period 1970–97. During the period 1970–75 Korean manufacturing output grew spectacularly by 20.4% a year, mainly attributable to 17.6% input growth. Yet, during this period TFP growth was moderate at 2.8% per annum. All industries enjoyed positive and considerable output and input growth. The highest average annual output growth of 58.2%, input growth of 39.4% and TFP growth of 18.8% came from the leather industry. In contrast, the plastics industry had the worst average annual TFP growth of –10.5%. Likewise, the average annual output growth rate of 15.2% between 1975 and 1980 was mostly accounted for by the 13.6% input growth, indicating a small TFP growth rate of 1.5%. Suddenly, the leather industry experienced the worst average annual output growth of –0.4% and TFP growth of –16.2%.

The average annual output growth of 11% over the 1980–85 period was respectively due to 4.3% TFP growth and 6.7% input growth. Compared with the last decade, TFP growth played a greater role in the process of output growth. On examining the contribution of the components to the average annual output growth of 17.1% for the period 1985–90, it was attributed to 9.8% input growth and 7.3% TFP growth. In the

1980s, except for the wood industry with negative input growth (1980–85) and miscellaneous petroleum with negative TFP growth (1985–90), all industries experienced positive output growth, input growth and impressive TFP growth.

TFP growth in the 1990–95 period continued rising by 5.4% a year. Due to the sizable TFP growth along with 7.0% input growth, manufacturing output grew strongly by 12.4% a year. In the recent period 1995–97, the 5.6% output growth was attributable to the 3.7% input growth and 1.9% TFP growth. Overall, it is suggested that TFP growth played a minor role in the 1970s but a relatively important one since 1980.

5.1.4 Singapore

Table 5.4 displays the decomposition of output growth into input growth and TFP growth for manufacturing industries in Singapore between 1970 and 1997. Singapore's manufacturing sector started with remarkable average annual output growth of 12.6% over the 1970–75 period. Nevertheless, such an impressive output performance was the result of even higher input growth of 18.4%. As a result, TFP growth turned out to be negative for most industries and average annual TFP growth was –5.8%. In terms of individual industries, the professional equipment industry especially had a significant 54.2% annual output growth, followed by non-electrical machinery with 39%. Likewise, the strong output growth in those two industries, professional equipment and non-electrical machinery, was mainly driven by massive factor accumulation with little TFP growth. Output growth during the 1975–80 period remained strong at 12.7% per annum, but average annual input growth dropped considerably from 18.4% to 9.5%. Therefore, part of the output growth was due to 3.2% TFP growth.

Unlike the 1970s, average annual output growth over the 1980–85 period fell drastically from 12.7% to only 3.2%. However, input growth on average stayed at a high level of 7.9% suggesting substantial –4.7% TFP growth. In fact, except for the professional equipment industry, all industries experienced negative TFP growth. On average, manufacturing output and factor inputs over the 1985–90 period grew by 12.7% and 9.8%, respectively, implying 2.8% TFP growth. In addition, apart from the beverages, furniture and electric machinery industries, all industries gained TFP growth.

The average annual output growth of 7.6% for the period 1990–95 was close to the input growth of 6.6%. Consequently, TFP growth for the entire manufacturing sector was insignificant at 1.0% per annum. The moderate 4.3% annual output growth in the period 1995–97 remained as a result of the intensive 8.5% input growth. Despite some industries gaining TFP growth, on average TFP growth was –4.3% per annum for the manufacturing sector.

5.1.5 Taiwan

Table 5.5 exhibits the decomposition of output growth into input growth and TFP growth for 20 manufacturing industries in Taiwan. Due to the change of industrial classification in Taiwan in 1981, the sample period is from 1981 to 1999. Despite output growth and input growth over the 1981–85 period being significant and positive for all industries, seven industries including printing, furniture and transport experienced negative TFP growth. Yet, some industries, such as chemical material and chemical products, enjoyed sizeable TFP growth of 12.2% and 9.3%, respectively. On average, the annual output growth of 8.2% for the manufacturing sector together with 5.7% input growth indicates TFP growth at an annual rate of 2.5%.

Output growth over the period 1985–90 remained significant and positive except for the wearing apparel (2.2%) and leather (0.9%) industries. Apart from the textile, wearing and wood industries, input growth was positive across industries. In comparison with the last period, the number of industries with negative TFP growth reduced to three. These were the leather, paper, and printing industries. The average annual output growth of 7.2% for the entire manufacturing sector was a result of 4.0% input growth and a substantial 3.2% TFP growth.

With the exception of the chemical material industry, the output growth for the 1990–95 period fell moderately for all industries, especially for labour-intensive industries, such as wearing apparel, leather and wood. Due to the moderate output growth of 5.0% and relatively higher input growth of 4.8%, average annual TFP growth for the manufacturing sector slowed down considerably to just 0.2%. Unlike the 1980s, input growth during this period almost accounted for output growth. Input growth between 1995 and 1999 increased by 9.1% a year but output growth dropped slightly to 5.8%. On average, input growth outweighed output growth by 3.3%, implying a substantial decline of 3.3% in the level of TFP. As opposed to the 1980s, TFP growth played no role in the 1990s as input growth completely accounted for output growth.

Table 5.1 Sources of output growth: average annual growth rates of output, input, and TFP in Hong Kong's manufacturing industries (percent)

Industries	1976–80			1980–85			1985–90			1990–95			1995–97		
	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP
311 Food products	8.2	5.8	2.4	2.5	1.8	0.7	8.9	2.8	6.0	2.2	-1.4	3.5	-4.5	-6.4	1.9
313 Beverages	5.6	6.9	-1.3	6.0	5.4	0.6	1.3	-3.0	4.3	-1.1	-1.9	0.8	#	#	#
321 Textiles	0.3	-1.0	1.3	0.1	-2.6	2.7	4.5	1.1	3.4	-13.6	-14.9	1.4	-3.8	-8.6	4.8
322 Wearing apparel	6.2	2.5	3.8	-2.4	0.3	-2.7	0.6	-2.2	2.8	-15.9	-19.4	3.6	-4.5	-9.3	4.8
323 Leather products	20.8	13.6	7.2	-9.3	-3.7	-5.5	-0.3	-7.0	6.7	-14.0	-20.5	6.5	-7.9	-14.0	6.1
324 Footwear	14.1	4.4	9.8	2.3	6.5	-4.2	-19.6	-12.0	-7.5	-50.4	-48.1	-2.4	-1.4	-7.7	6.3
331 Wood products	1.3	4.8	-3.5	-5.2	-5.2	-0.1	-4.5	-4.5	0.0	-11.5	-18.6	7.1	-7.6	-9.4	1.8
332 Furniture	7.1	2.6	4.6	-1.4	0.7	-2.1	-3.9	-6.8	2.9	-37.1	-35.7	-1.4	2.4	-6.8	9.1
341 Paper and products	14.4	10.1	4.3	-2.6	-0.9	-1.7	14.3	11.6	2.6	-10.3	-12.6	2.3	-4.4	-9.3	4.9
342 Printing and publishing	13.7	8.5	5.1	5.2	3.4	1.7	10.3	6.1	4.2	0.5	3.7	-3.2	-1.9	-9.2	7.3
351 +352 (Chemical products)	10.1	3.7	6.4	-0.4	0.9	-1.2	6.2	-0.1	6.3	-4.8	-7.2	2.3	0.3	-6.7	7.0
355 Rubber products	-3.7	-1.6	-2.1	-8.9	-9.3	0.3	-9.1	-13.7	4.5	-17.6	-21.5	3.9	0.4	-1.2	1.6
356 Plastic products	6.2	2.7	3.5	3.0	1.4	1.6	-3.8	-6.3	2.5	-25.3	-30.1	4.8	-4.5	-6.6	2.1
36 Non-metal mineral products	17.8	5.1	12.8	0.3	6.0	-5.7	3.8	-8.0	11.8	7.5	-1.1	8.6	-24.1	-9.6	-14.5
371 +372 (Basic metals)	1.8	5.4	-3.6	-10.5	-0.2	-10.3	8.4	-4.7	13.1	1.8	-6.3	8.1	-14.4	-8.0	-6.4
381 Fabricated metal products	13.7	8.8	4.9	-5.2	-2.6	-2.6	0.8	-3.8	4.6	-11.8	-15.8	4.0	-5.7	-10.4	4.7
382 Non-electrical machinery	12.4	5.1	7.3	5.9	5.8	0.2	22.3	14.6	7.7	-7.6	-11.1	3.4	-6.8	-9.2	2.4
383 Electric machinery	14.8	7.5	7.3	-4.1	1.5	-5.6	0.5	-3.6	4.1	-1.8	-14.2	12.4	-4.9	-7.5	2.7
384 Transport equipment	4.6	8.7	-4.1	-0.9	-1.3	0.4	7.1	-2.1	9.1	-1.2	-2.8	1.6	-6.4	-7.4	1.0
385 Professional equipment	24.4	17.0	7.4	-3.2	0.1	-3.3	4.3	-1.8	6.1	-12.1	-17.8	5.7	-6.6	-9.9	3.3
390 Other manufactured	6.6	4.5	2.1	1.5	0.6	0.9	2.7	1.4	1.3	-9.2	-13.2	3.9	-2.4	-7.6	5.3
300 Manufacturing	8.2	4.5	3.8	-1.0	0.3	-1.3	3.8	-0.3	4.1	-8.8	-12.5	3.8	-4.8	-8.3	3.6

Notes: 1. Due to rounding, figures above may not add up.
2. # denotes the removal of industry due to negative capital stock in 1995 and 1996.
3. The period covered for beverages industry is from 1976 to 1994. So, the result of the 1990–95 period for beverages industry represents the 1990–94 period.
4. Non-metal mineral products (36) industry includes pottery, china, earthenware (361), glass and product (362), and other non-metallic mineral (369) industries.

Source: Author's calculation.

Table 5.2 Sources of output growth: average annual growth rates of output, input, and TFP in Japan's manufacturing industries (percent)

3-digit industries	1965–70			1970–75			1975–80			1980–85			1985–90			1990–95			1995–98		
	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP
311 Food	7.9	4.5	3.4	9.4	4.3	5.0	5.1	1.9	3.3	4.1	1.9	2.2	4.5	3.5	1.0	1.1	2.3	-1.2	1.0	0.9	0.2
313 Beverages	10.0	2.3	7.7	5.3	2.0	3.3	1.7	-2.0	3.7	1.0	-3.0	4.0	3.0	1.7	1.3	10.1	4.0	6.1	2.6	1.1	1.4
321 Textiles	7.6	2.0	5.6	1.2	0.7	0.5	2.0	-3.4	5.4	-0.4	-2.3	1.9	1.3	-0.2	1.4	-4.6	-2.5	-2.1	5.9	-4.1	10.0
322 Wearing	12.4	6.3	6.1	10.7	7.3	3.4	3.3	0.5	2.9	1.5	0.5	1.0	4.9	3.2	1.7	-3.6	-2.0	-1.6	-2.9	-4.7	1.8
323 Leather	6.9	3.3	3.6	5.9	2.2	3.7	4.0	0.8	3.2	1.8	-1.1	2.8	2.7	1.3	1.4	-1.5	0.4	-1.9	3.0	-2.9	5.8
324 Footwear	10.8	2.8	8.0	4.9	2.3	2.6	7.3	2.2	5.1	-1.3	-0.5	-0.8	6.0	2.8	3.2	8.5	5.6	2.8	-5.4	-2.9	-2.5
331 Wood	10.1	3.8	6.3	2.5	1.9	0.7	4.0	-2.7	6.8	-5.6	-5.3	-0.3	4.0	-0.3	4.3	-0.3	-1.4	1.1	-1.4	0.3	-1.7
332 Furniture	11.6	5.7	5.9	9.5	6.2	3.3	5.1	-0.3	5.3	-0.1	-1.0	0.8	6.4	2.7	3.7	0.9	1.0	-0.2	-0.9	0.0	-0.9
341 Paper	9.4	5.1	4.3	4.0	4.1	-0.1	3.6	-0.2	3.8	0.8	-1.4	2.1	6.3	3.2	3.1	1.1	1.6	-0.6	0.9	0.0	1.0
342 Printing	10.6	4.3	6.3	7.7	3.5	4.2	6.2	0.8	5.4	3.7	2.8	0.9	6.5	5.3	1.2	0.6	2.0	-1.4	2.2	1.1	1.1
351 Industrial chem.	11.2	4.0	7.2	-3.0	1.4	-4.4	3.7	-2.2	5.9	3.8	-1.5	5.2	6.1	0.2	5.9	-2.5	-0.4	-2.1	-0.3	-0.5	0.2
352 Other chemicals	11.5	4.7	6.8	6.0	3.5	2.5	6.5	1.1	5.4	4.7	2.9	1.7	7.0	3.5	3.5	3.1	3.9	-0.8	0.5	1.0	-0.5
353 Petroleum refineries	10.9	6.6	4.3	8.2	7.6	0.6	14.2	0.1	14.1	-7.4	-2.4	-5.1	-9.2	-1.8	-7.4	11.1	2.9	8.2	-17.2	0.4	-17.6
354 Misc. petroleum	14.0	12.7	1.4	12.2	7.0	5.2	3.4	0.1	3.3	-8.2	-3.6	-4.5	5.2	-1.8	7.0	-2.5	-3.4	0.8	1.4	-1.6	3.0
355 Rubber	7.7	4.3	3.4	4.9	2.7	2.2	6.0	0.2	5.8	3.8	2.7	1.1	6.0	3.0	3.0	-2.1	0.2	-2.3	1.8	-0.9	2.7
356 Plastic	18.9	9.4	9.5	8.5	6.0	2.4	7.9	1.9	6.0	7.0	5.1	1.9	6.2	5.6	0.6	-0.2	2.5	-2.7	2.3	0.9	1.4
361 Pottery	10.1	4.8	5.3	6.5	2.8	3.7	3.6	-0.3	3.8	-0.1	1.9	-2.0	1.9	1.7	0.3	2.1	0.6	1.4	3.2	2.3	0.9
362 Glass	11.5	5.6	5.9	-0.3	2.4	-2.7	6.5	-0.9	7.4	6.6	2.8	3.7	4.7	4.1	0.6	-6.4	-1.2	-5.2	2.1	-1.3	3.4
369 Other non-metallic	13.3	6.1	7.2	5.9	3.7	2.2	6.4	-0.3	6.7	-0.6	-1.6	1.0	5.2	0.4	4.8	0.1	1.0	-0.9	-1.3	0.2	-1.4
371 Iron and steel	13.5	6.3	7.2	1.4	2.8	-1.4	9.6	-0.8	10.3	-1.1	-1.6	0.4	2.9	-2.1	5.0	-7.2	-1.7	-5.4	-0.1	-2.8	2.6
372 Non-ferrous metal	13.5	8.9	4.6	1.8	4.6	-2.7	10.7	-0.9	11.6	-7.2	-2.4	-4.9	6.3	1.7	4.5	-3.9	-0.4	-3.5	3.0	-0.7	3.7
381 Fabricated metal	15.6	7.3	8.4	3.5	4.8	-1.3	5.4	-0.9	6.3	3.1	0.7	2.4	7.2	4.0	3.2	1.1	2.8	-1.8	0.2	0.4	-0.2
382 Non-electrical mach.	18.2	7.6	10.5	3.1	3.6	-0.5	5.8	-0.3	6.1	6.1	3.9	2.2	6.9	4.0	2.9	-1.8	2.2	-4.0	3.2	0.8	2.4
383 Electric mach.	16.6	8.9	7.8	-1.1	2.5	-3.6	10.5	1.8	8.7	9.6	8.5	1.1	4.8	5.0	-0.2	-3.2	-0.1	-3.1	3.4	1.4	2.1
384 Transport equip.	12.2	9.0	3.2	5.2	5.0	0.3	4.8	0.4	4.5	6.7	3.3	3.4	4.7	2.3	2.3	-1.3	1.9	-3.1	3.7	-0.2	3.9
385 Prof. Equipment	12.9	5.6	7.3	7.5	4.1	3.4	8.1	3.5	4.6	3.8	2.6	1.2	1.9	2.6	-0.7	5.5	2.7	2.8	4.5	-0.2	4.6
390 Other manufactured	10.0	4.3	5.7	4.5	2.1	2.4	4.3	-0.2	4.5	4.4	1.3	3.2	4.8	2.8	2.0	0.7	1.7	-1.1	-1.9	-0.9	-1.0
300 Manufacturing	12.7	6.1	6.6	3.7	3.5	0.2	6.2	0.0	6.2	3.8	2.1	1.7	5.2	3.0	2.2	-0.8	1.3	-2.2	1.8	0.2	1.5

Note: Due to rounding, figures above may not add up.
Source: As in Table 5.1.

Table 5.3 Sources of output growth: average annual growth rates of output, input, and TFP in Korea's manufacturing industries (percent)

3-digit industries	1970–75			1975–80			1980–85			1985–90			1990–95			1995–97		
	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP
311 Food products	15.0	18.0	-3.1	15.8	10.9	4.9	7.3	7.1	0.3	14.4	7.3	7.1	10.3	5.5	4.8	6.2	1.3	5.0
321 Textiles	22.1	16.7	5.4	10.0	8.5	1.6	5.8	1.0	4.8	7.3	4.3	3.0	8.0	1.2	6.8	0.3	-4.3	4.6
322 Wearing apparel	27.4	28.1	-0.7	15.6	12.1	3.5	8.5	6.1	2.4	12.2	4.8	7.4	11.0	0.7	10.3	-1.7	-3.8	2.1
323 Leather products	58.2	39.4	18.8	-0.4	15.7	-16.2	14.9	7.4	7.4	21.6	11.7	9.9	1.7	0.1	1.7	-5.2	-6.5	1.4
324 Footwear	22.3	23.6	-1.3	23.8	21.9	1.9	14.2	7.5	6.6	13.4	4.5	8.8	15.9	18.3	-2.3	-2.9	-11.1	8.2
331 Wood products	13.2	9.6	3.6	0.2	5.9	-5.6	3.3	-1.6	4.9	16.9	1.9	15.0	10.8	3.6	7.2	1.4	-3.2	4.6
332 Furniture	11.6	10.0	1.6	27.8	20.6	7.2	15.6	10.3	5.3	24.0	12.4	11.6	13.5	22.4	-8.9	1.7	-5.7	7.4
341 Paper and products	15.8	13.5	2.3	15.7	10.9	4.7	10.8	6.4	4.4	15.4	10.6	4.8	13.3	7.6	5.7	6.8	4.4	2.4
342 Printing and publishing	12.3	10.3	2.0	16.3	11.3	5.0	11.7	8.4	3.3	17.5	8.0	9.5	12.6	9.4	3.2	3.5	2.3	1.2
351 Industrial chemicals	18.2	17.6	0.5	11.3	7.5	3.8	6.4	6.4	0.0	16.5	9.0	7.5	10.6	8.7	1.9	26.1	12.0	14.1
352 Other chemicals	18.3	13.7	4.6	15.8	14.0	1.8	8.2	7.4	0.9	17.6	11.7	5.9	5.7	7.4	-1.7	13.7	5.2	8.5
354 Miscellaneous petroleum	13.5	8.0	5.5	15.1	6.0	9.2	7.9	5.3	2.6	4.2	5.1	-0.9	-4.5	-1.7	-2.8	-15.8	-10.5	-5.3
355 Rubber products	23.7	23.7	0.0	19.8	14.8	5.0	8.0	5.8	2.1	17.0	10.8	6.3	-9.3	-17.1	7.8	6.3	2.4	3.9
356 Plastic products	18.6	29.2	-10.5	27.6	14.4	13.1	15.1	11.2	3.9	19.8	15.0	4.7	23.5	14.2	9.3	-24.7	-2.5	-22.2
361 Pottery, china, earthenware	11.1	-1.2	12.3	34.5	12.6	21.9	5.2	3.6	1.6	11.5	5.6	5.8	7.9	4.4	3.5	-2.1	-6.2	4.1
362 Glass and products	17.5	14.6	2.9	14.9	16.0	-1.1	10.3	9.0	1.3	16.2	9.0	7.2	13.1	6.9	6.2	1.1	4.4	-3.4
369 Other non-metallic mineral	18.0	4.1	13.9	12.7	10.4	2.4	6.3	5.2	1.1	17.6	6.6	11.1	10.8	8.4	2.4	3.9	-0.7	4.5
371 Iron and steel	28.3	24.2	4.1	16.4	19.3	-2.9	11.1	5.3	5.8	15.0	6.6	8.4	9.9	4.5	5.4	2.4	3.8	-1.4
372 Non-ferrous metals	28.0	15.0	12.9	24.2	13.2	11.0	6.1	9.2	-3.1	18.3	9.5	8.8	14.3	8.4	5.8	-3.1	-2.6	-0.6
381 Fabricated metal products	19.0	17.0	2.1	20.0	20.1	-0.1	14.9	9.5	5.3	21.2	10.0	11.2	12.2	9.4	2.7	4.6	0.4	4.2
382 Non-electrical machinery	23.4	18.3	5.1	22.5	27.9	-5.4	16.8	8.4	8.4	24.3	12.8	11.5	16.1	12.6	3.5	16.6	9.8	6.8
383 Electric machinery	30.5	28.0	2.6	16.4	20.0	-3.7	18.0	9.9	8.0	21.3	15.1	6.2	17.2	6.3	10.9	-2.8	4.2	-7.0
384 Transport equipment	14.2	18.9	-4.7	21.5	18.3	3.1	19.2	10.5	8.7	18.7	11.7	7.0	14.0	11.1	3.0	16.6	8.6	8.0
385 Professional equipment	32.4	18.3	14.0	21.3	22.6	-1.3	7.5	5.9	1.6	20.2	11.2	9.0	6.8	1.2	5.6	19.3	14.8	4.5
390 Other manufactured products	10.5	13.2	-2.7	13.5	11.5	2.0	11.2	7.9	3.3	14.4	6.9	7.5	2.6	-2.8	5.4	-4.7	-3.7	-1.0
300 Manufacturing	20.4	17.6	2.8	15.2	13.6	1.5	11.0	6.7	4.3	17.1	9.8	7.3	12.4	7.0	5.4	5.6	3.7	1.9

Note and source: As in Table 5.2.

Table 5.4 Sources of output growth: average annual growth rates of output, input, and TFP in Singapore's manufacturing industries (percent)

Industries	1970–75			1975–80			1980–85			1985–90			1990–95			1995–97		
	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP
311 Food products	3.3	4.8	-1.5	5.0	5.2	-0.2	5.7	8.1	-2.4	5.8	1.0	4.8	4.2	7.5	-3.3	13.8	8.2	5.6
313 Beverages	-0.6	5.8	-6.4	7.5	5.8	1.7	5.3	9.7	-4.3	6.3	14.8	-8.5	0.9	-5.2	6.1	0.9	-4.9	5.8
321 Textiles	13.5	19.1	-5.5	7.0	-4.3	11.2	-20.4	-16.3	-4.1	12.7	0.9	11.8	-8.9	-6.9	-2.0	-3.2	-7.6	4.5
322 Wearing apparel	16.6	22.3	-5.8	15.8	5.9	9.9	2.0	3.5	-1.5	6.7	3.4	3.3	-13.3	-5.7	-7.6	-16.7	-18.0	1.3
323 Leather products	-0.1	2.2	-2.3	14.7	11.0	3.7	-6.9	-2.4	-4.4	9.0	-0.2	9.3	7.1	10.5	-3.3	11.4	0.3	11.1
324 Footwear	3.6	3.4	0.1	3.3	7.9	-4.6	-11.9	-3.2	-8.7	4.2	-8.2	12.3	-5.1	-7.1	2.0	-11.6	-14.7	3.1
331 Wood products	-4.3	11.0	-15.3	10.1	3.0	7.1	-15.7	-13.1	-2.6	-1.1	-9.9	8.9	-5.5	-8.5	3.0	4.4	6.1	-1.7
332 Furniture	2.6	13.9	-11.3	22.1	19.7	2.4	6.3	7.5	-1.2	1.8	2.5	-0.6	4.2	0.8	3.3	4.1	8.2	-4.1
341 Paper and products	9.3	11.7	-2.4	16.3	6.3	10.0	9.4	13.0	-3.6	11.1	5.7	5.3	4.3	8.2	-3.9	-2.3	0.7	-3.0
342 Printing and publishing	7.6	7.5	0.1	9.9	8.7	1.2	9.3	12.2	-3.0	10.4	7.1	3.3	8.4	6.2	2.2	3.4	3.9	-0.5
351 Industrial chemicals	10.4	14.6	-4.2	12.2	5.6	6.6	17.3	19.0	-1.7	23.0	12.0	11.1	-11.3	4.0	-15.3	-0.2	1.2	-1.4
355 Rubber products	-10.7	0.6	-11.2	4.9	0.3	4.6	-17.2	-3.8	-13.5	4.4	-1.9	6.3	8.6	2.9	5.7	5.1	7.9	-2.7
356 Plastic products	14.3	21.9	-7.6	23.7	15.8	7.9	1.6	5.2	-3.5	17.4	12.1	5.3	6.5	7.3	-0.8	0.2	6.4	-6.3
361 +362 Pottery, glass & product	-4.6	-7.8	3.2	9.5	5.3	4.2	-18.5	-4.1	-14.4	31.6	27.5	4.1	16.8	0.7	16.2	6.6	24.0	-17.4
369 Other non-metallic mineral	21.2	14.1	7.1	3.2	2.0	1.3	8.5	21.3	-12.8	-4.7	-7.5	2.9	11.2	1.4	9.7	5.1	17.5	-12.5
371 Iron and steel	12.1	20.7	-8.7	12.9	-2.6	15.6	-7.4	10.2	-17.6	8.2	0.6	7.6	-4.7	4.4	-9.1	-4.5	-6.6	2.2
372 Non-ferrous metals	5.5	14.6	-9.2	6.1	-5.1	11.2	10.0	15.6	-5.6	11.3	3.0	8.3	-15.5	-1.9	-13.6	-12.2	-5.8	-6.4
381 Fabricated metal products	7.2	11.6	-4.4	12.8	12.5	0.3	5.2	13.3	-8.1	12.0	6.8	5.2	8.2	8.5	-0.3	-0.6	7.7	-8.2
382 Non-electrical machinery	39.0	38.6	0.5	8.7	13.5	-4.8	0.7	9.1	-8.4	34.2	18.6	15.6	11.4	11.3	0.2	10.8	14.0	-3.3
383 Electric machinery	19.1	29.1	-10.0	20.2	19.0	1.2	7.4	10.2	-2.8	5.5	13.3	-7.8	9.9	2.9	7.0	-5.6	6.8	-12.4
384 Transport equipment	12.7	21.4	-8.7	9.3	2.0	7.3	-3.6	3.2	-6.7	7.0	0.8	6.2	5.2	11.2	-6.0	16.0	4.8	11.2
385 Professional equipment	54.2	51.3	2.9	7.5	3.6	4.0	-0.2	-7.7	7.5	10.4	6.6	3.8	11.1	6.5	4.7	7.7	2.7	5.0
390 Other manufactured products	-4.9	-7.3	2.4	21.2	9.7	11.5	-5.6	2.2	-7.8	7.7	5.8	1.8	-3.2	-2.1	-1.1	-1.0	-4.0	3.1
300 Manufacturing	12.6	18.4	-5.8	12.7	9.5	3.2	3.2	7.9	-4.7	12.7	9.8	2.8	7.6	6.6	1.0	4.3	8.5	-4.3

Note and source: As in Table 5.2.

Table 5.5 Sources of output growth: average annual growth rates of output, input, and TFP in Taiwan's manufacturing industries (percent)

Industries	1981–85			1985–90			1990–95			1995–99		
	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP	Output	Input	TFP
Food, beverages and tobacco	8.9	5.4	3.5	3.2	2.5	0.8	2.4	3.9	-1.5	-1.3	0.7	-2.0
Textile mill products	5.2	5.3	-0.1	1.7	-0.8	2.5	-1.2	0.5	-1.8	0.9	6.1	-5.3
Wearing apparel, accessories*	5.8	4.9	0.9	-2.2	-4.2	2.0	-12.2	-3.4	-8.8	-1.9	6.0	-7.9
Leather, fur and products	14.8	15.0	-0.3	-0.9	1.8	-2.8	-10.3	-2.7	-7.7	-4.7	1.8	-6.5
Wood and bamboo products	7.7	0.1	7.6	0.3	-0.3	0.5	-6.3	-8.2	1.9	-7.7	-5.6	-2.2
Furniture and fixtures	4.4	7.9	-3.6	10.5	3.1	7.4	5.2	-0.1	5.3	3.4	0.2	3.2
Pulp, paper and paper products	3.7	4.0	-0.4	2.5	5.9	-3.4	-1.7	5.7	-7.4	2.9	6.1	-3.2
Printing processings	2.6	9.8	-7.2	9.1	10.5	-1.4	1.3	5.4	-4.0	3.4	3.5	-0.1
Chemical material	13.2	1.0	12.2	6.5	4.0	2.5	8.6	4.2	4.4	5.5	7.9	-2.4
Chemical products	14.8	5.5	9.3	11.6	10.2	1.4	11.3	7.0	4.3	5.9	2.3	3.6
Rubber products	8.6	8.0	0.6	3.3	1.6	1.7	1.3	3.2	-2.0	-0.6	7.1	-7.7
Plastic products	14.0	7.1	6.9	7.7	1.7	6.0	0.1	-0.1	0.2	2.4	6.1	-3.7
Non-metallic mineral products	4.3	2.8	1.6	7.8	0.9	7.0	7.4	4.9	2.5	-1.9	1.3	-3.2
Basic metal industries	10.7	4.5	6.1	8.2	3.4	4.8	6.3	9.1	-2.8	7.7	6.5	1.2
Fabricated metal products	9.1	9.4	-0.3	12.7	10.1	2.6	6.2	6.9	-0.6	1.5	6.1	-4.6
Machinery and equipments	6.1	4.4	1.6	13.4	8.3	5.1	8.6	7.8	0.7	2.9	8.0	-5.1
Electrical & electronic machinery	10.7	8.0	2.7	14.3	9.2	5.1	12.8	7.9	4.9	15.0	18.5	-3.6
Transport equipments	1.8	4.2	-2.4	11.4	4.9	6.5	3.0	6.9	-3.9	-1.8	7.0	-8.8
Precision instruments	9.2	7.1	2.0	7.2	7.0	0.2	-1.6	1.6	-3.2	-0.3	2.8	-3.0
Other industrial products	8.8	8.4	0.5	2.3	2.0	0.3	-3.9	-2.7	-1.2	-2.7	0.7	-3.4
Manufacturing	8.2	5.7	2.5	7.2	4.0	3.2	5.0	4.8	0.2	5.8	9.1	-3.3

Note: 1. * denotes wearing apparel, accessories and other textile products industry.
2. Due to rounding, figures above may not add up.

Source: As in Table 5.2.

5.2 SOURCES OF LONG-TERM OUTPUT GROWTH

The focus of this section is identification of the sources of long-term output growth. Following the decomposition approach described in Chapter 3, long-term output growth across five East Asian manufacturing industries is decomposed into input growth and TFP growth. Special attention will also be paid to several leading industries within each manufacturing sector. The estimates of output, input and TFP growth in the following tables are all presented on an average annual basis; input and TFP growth estimates for the entire sample periods are available in Tables 5.18 and 5.19. The discussion commences with Hong Kong, followed by Japan, Korea, Singapore and Taiwan, respectively.

5.2.1 Hong Kong

To realise the development of individual industries over the past few decades, it is informative to present their shares in the overall manufacturing sector prior to further discussion. Table 5.6 presents the average shares of industries in Hong Kong's manufacturing sector over the period 1976–97. The shares of the food, printing and publishing, and non-electrical machinery industries have been increasing over time as shown in Table 5.6. Based on shares in the manufacturing sector, three major industries over the period 1976–97 were wearing apparel with 22%, textiles with 14.6% and electric machinery with 12.8%. Overall, these three leading industries accounted for nearly 55% of total manufacturing output in the late 1970s and just over 40% in the 1990s. Even without considering the tobacco industry, the remaining 21 industries still made up over 97% of total manufacturing output between 1976 and 1997. Because the value added data for the petroleum refineries (ISIC 353) and miscellaneous petroleum (ISIC 354) industries are not available until the late 1980s, Table 5.6 does not include these two industries.

Table 5.7 gives the detailed decomposition of output growth across manufacturing industries in Hong Kong during the 1976–97 period.[62] Irrespective of their declining manufacturing share in the overall economy, some industries grew remarkably, for

[62] It should be noted that the final weighted growth rate for the manufacturing sector does not include the beverages (1995–97) and footwear (1993–97) industries due to their removal from the sample; see the Appendix in Chapter 4 for details.

example, non-electrical machinery with an average annual rate of 6.6%, printing and publishing with 6.2%, and food with 4.3%. Those generally regarded as labour-intensive industries shrank sharply in output growth, such as footwear (–13.5% per annum), rubber (–9.2%), furniture (–8.5%). Positive input growth took place in the printing and publishing (3.6% per annum) and non-electrical machinery (2.7%) industries. Yet, there were more industries with negative input growth. Out of 21 industries, 16 experienced negative input growth, where the worst average annual input growth occurred in the footwear with –12.5% industry, followed by rubber with –12.4%, and furniture with –10.3%.

Table 5.6 The average shares of individual industries in the overall manufacturing in Hong Kong, 1976–97 (percent)

Industries	1976–79	1980–84	1985–89	1990–94	1995–97	1976–97
311 Food products	2.3	2.4	2.5	3.8	6.2	3.1
313 Beverages	1.5	1.4	1.6	1.8	2.4	1.7
314 *Tobacco*	1.3	1.1	1.8	4.5	2.9	2.3
321 Textiles	16.4	13.4	15.9	14.4	11.9	14.6
322 Wearing apparel	26.5	24.8	22.4	18.6	14.1	22.0
323 Leather products	0.5	0.5	0.4	0.3	0.2	0.4
324 Footwear	0.6	0.7	0.7	0.2	0.0	0.5
331 Wood products	0.9	0.7	0.4	0.3	0.3	0.5
332 Furniture	1.0	0.9	0.7	0.4	0.1	0.7
341 Paper and products	1.3	1.4	1.9	2.5	2.1	1.8
342 Printing and publishing	3.6	4.5	5.2	8.4	12.7	6.3
351 +352 (Chemical products)	1.6	1.6	1.6	2.0	2.5	1.8
355 Rubber products	0.5	0.3	0.2	0.1	0.1	0.2
356 Plastic products	8.6	8.1	8.4	4.8	2.8	7.0
36 Non-metal mineral products	1.0	1.0	1.0	1.1	1.6	1.1
371 +372 (Basic metals)	1.1	0.8	0.6	0.8	1.1	0.8
381 Fabricated metal products	7.5	7.4	6.8	5.9	4.9	6.6
382 Non-electrical machinery	2.3	3.4	4.5	8.5	9.5	5.3
383 Electric machinery	11.9	14.8	12.9	10.7	13.6	12.8
384 Transport equipment	2.4	2.5	2.3	3.3	3.9	2.7
385 Professional equipment	3.6	4.8	4.3	4.1	3.6	4.2
390 Other manufactured products	3.7	3.6	3.8	3.5	3.7	3.6

Notes: 1. Due to rounding, figures above may not add up.
2. The industry in *italic* is excluded in the estimation.
3. The average share is calculated by the sum of value added of each industry divided by the sum of manufacturing value added over the certain period at constant 1990 price, i.e., $(y_i^t + y_i^{t-1})/(Y^t + Y^{t-1})$, not a simple average share.

Source: Author's calculation based on the UNIDO database.

Table 5.7 Decomposition of output growth: average annual growth rates of output, input, and TFP by industry in Hong Kong, 1976–97

Industries	Output	Input		TFP	
311 Food products	4.3	1.4	(33%)	2.9	(67%)
313 Beverages	2.6	1.6	(64%)	0.9	(36%)
321 Textiles	-2.4	-4.8	–	2.3	–
322 Wearing apparel	-3.5	-5.3	–	1.9	–
323 Leather products	-2.4	-6.5	–	4.1	–
324 Footwear	-13.6	-12.5	–	-1.0	–
331 Wood products	-5.5	-7.8	–	2.2	–
332 Furniture	-8.5	-10.3	–	1.7	–
341 Paper and products	2.6	0.3	(10%)	2.4	(90%)
342 Printing and publishing	6.2	3.6	(57%)	2.7	(43%)
351 +352 (Chemical products)	2.2	-0.5	(-23%)	2.7	(123%)
355 Rubber products	-9.2	-12.4	–	3.3	–
356 Plastic products	-5.4	-8.5	–	3.0	–
36 Non-metal mineral products	3.9	-0.2	(-5%)	4.0	(105%)
371 +372 (Basic metals)	-1.1	-2.7	–	1.6	–
381 Fabricated metal products	-1.8	-5.0	–	3.2	–
382 Non-electrical machinery	6.6	2.7	(40%)	4.0	(60%)
383 Electric machinery	1.1	-3.6	(-337%)	4.6	(437%)
384 Transport equipment	1.4	-1.0	(-72%)	2.5	(172%)
385 Professional equipment	1.4	-1.4	(-101%)	2.8	(201%)
390 Other manufactured	-0.2	-2.6	–	2.5	–
300 Manufacturing	-0.3	-3.0	–	2.7	–

Notes: 1. Due to rounding, figures above may not add up.
2. Figures in percentage point in parenthesis denote contributions to output growth. The relative contributions are calculated based on Table 5.18, *not* annual input and TFP growth estimates.
3. The calculation of percentage contributions to negative output growth is not meaningful so it is denoted by '–'.

Source: As in Table 5.1.

With the exception of the footwear industry with –1.0%, average annual TFP growth for all industries between 1976 and 1997 was positive and ranged from 0.9% in the beverages industry to 4.6% in electric machinery. A number of industries with substantial TFP growth include leather with 4.1% and non-metal mineral products with 4.0%. On the other hand, lower TFP growth tends to take place in labour-intensive industries, such as basic metals with 1.6% and furniture with 1.7%. Overall, the cause of output decline in Hong Kong's manufacturing sector over the 1976–97 period was mainly due to the rapid reallocation of manufacturing production to mainland China since the mid-1980s, i.e., the loss of comparative advantages in labour-intensive industries. The manufacturing relocation also explains why Hong Kong's manufacturing share in GDP declined so quickly, from 20% in the mid-1980s to 5.5% in 1997. Due to the considerable reduction in labour and capital inputs by 3.0% per annum, output growth fell by 0.3%, indicating a considerable TFP growth of 2.7%.

5.2.2 Japan

Table 5.8 The average shares of individual industries in the overall manufacturing in Japan, 1965–1998 (percent)

Industries	1965–69	1970–79	1980–84	1985–89	1990–94	1995–98	1965–98
311 Food products	1.9	1.7	1.5	1.3	1.3	2.0	1.6
313 Beverages	—	—	—	0.2	0.3	0.3	0.2
314 *Tobacco*	7.3	5.8	4.2	3.5	2.9	2.5	4.0
321 Textiles	1.3	1.6	1.5	1.4	1.3	1.1	1.4
322 Wearing apparel	0.3	0.3	0.2	0.2	0.2	0.2	0.2
323 Leather products	0.2	0.2	0.2	0.2	0.2	0.2	0.2
324 Footwear	3.4	3.0	2.1	1.7	1.6	1.5	2.1
331 Wood products	0.9	1.1	1.0	1.0	1.0	1.0	1.0
332 Furniture	3.3	3.1	2.7	2.6	2.5	2.7	2.8
341 Paper and products	4.5	4.6	5.1	5.3	5.5	5.8	5.2
342 Printing and publishing	6.9	5.0	4.0	4.4	4.2	3.8	4.5
351 Industrial chemicals	4.1	4.4	4.9	5.2	5.6	6.3	5.2
352 Other chemicals	1.1	1.3	1.6	1.0	1.0	0.7	1.1
353 Petroleum refineries	0.2	0.3	0.3	0.2	0.2	0.2	0.2
354 Miscellaneous petroleum	1.4	1.2	1.2	1.3	1.3	1.2	1.2
355 Rubber products	1.8	2.6	3.0	3.4	3.6	3.6	3.2
356 Plastic products	0.5	0.5	0.4	0.4	0.3	0.4	0.4
361 Pottery, china, earthenware	1.1	1.0	0.9	1.0	0.9	0.7	0.9
362 Glass and products	3.3	3.6	3.5	3.1	3.1	3.0	3.3
369 Other non-metallic mineral	7.3	7.3	6.7	5.6	5.0	3.9	5.8
371 Iron and steel	1.9	2.0	1.7	1.3	1.3	1.2	1.5
372 Non-ferrous metals	6.3	6.9	6.4	6.6	7.4	7.6	7.0
381 Fabricated metal products	10.5	11.5	12.1	12.8	13.5	13.9	12.7
382 Non-electrical machinery	10.6	10.7	13.5	15.1	14.4	13.6	13.2
383 Electric machinery	9.8	9.8	10.2	10.2	10.5	10.9	10.3
384 Transport equipment	1.3	1.5	1.7	1.5	1.5	2.1	1.6
385 Professional equipment	1.8	1.6	1.6	1.5	1.6	1.6	1.6
390 Other manufactured	1.9	1.7	1.5	1.3	1.3	2.0	1.6

Note and source: As in Table 5.6.

Table 5.8 shows the average shares of Japan's 3-digit industries in the manufacturing sector over the period 1965–98. The highest share was electric machinery with 13.2%, followed by non-electrical machinery with 12.7% and transport equipment with 10.3%. The sum of the three major industries' shares exceeded 36% of total manufacturing output. However, a number of industries, including textiles, wood products, and iron and steel, experienced declining shares over time. Irrespective of the removal of the tobacco industry due to the incomplete data, the remaining 27 industries still accounted for 99.8% of total manufacturing output.

Table 5.9 Decomposition of output growth: average annual growth rates of output, input, and TFP by industry in Japan, 1965–98

Industries	Output	Input		TFP	
311 Food products	4.9	2.8	(57%)	2.1	(43%)
313 Beverages	4.9	0.8	(16%)	4.1	(84%)
321 Textiles	1.6	-1.3	(-82%)	2.9	(182%)
322 Wearing apparel	4.2	2.0	(48%)	2.2	(52%)
323 Leather products	3.3	0.8	(23%)	2.5	(77%)
324 Footwear	5.0	2.1	(42%)	2.9	(58%)
331 Wood products	2.1	-0.6	(-28%)	2.7	(128%)
332 Furniture	5.0	2.2	(44%)	2.8	(56%)
341 Paper and products	3.9	1.8	(47%)	2.1	(53%)
342 Printing and publishing	5.6	2.9	(52%)	2.7	(48%)
351 Industrial chemicals	2.9	0.1	(2%)	2.8	(98%)
352 Other chemicals	5.9	3.0	(50%)	2.9	(50%)
353 Petroleum refineries	2.6	2.0	(77%)	0.6	(23%)
354 Miscellaneous petroleum	3.8	1.4	(37%)	2.4	(63%)
355 Rubber products	4.2	1.8	(43%)	2.4	(57%)
356 Plastic products	7.5	4.7	(63%)	2.8	(37%)
361 Pottery, china, earthenware	3.9	1.8	(47%)	2.1	(53%)
362 Glass and products	3.6	1.7	(46%)	1.9	(54%)
369 Other non-metallic mineral	4.5	1.5	(32%)	3.0	(68%)
371 Iron and steel	2.9	0.1	(4%)	2.8	(96%)
372 Non-ferrous metals	3.5	1.6	(47%)	1.8	(53%)
381 Fabricated metal products	5.5	2.8	(52%)	2.6	(48%)
382 Non-electrical machinery	6.1	3.2	(53%)	2.9	(47%)
383 Electric machinery	6.0	4.1	(69%)	1.9	(31%)
384 Transport equipment	5.2	3.2	(62%)	2.0	(38%)
385 Professional equipment	6.4	3.2	(50%)	3.2	(50%)
390 Other manufactured	4.2	1.7	(40%)	2.5	(60%)
300 Manufacturing (weighted)	4.8	2.3	(48%)	2.5	(52%)

Notes: 1. As in Table 5.7.
2. The final weighted growth rates for manufacturing sector does not include the tobacco industry.
Source: As in Table 5.1.

Table 5.9 reports the decomposition of output growth for Japanese manufacturing industries during the 1965–98 period. Output growth for all industries was positive; in particular, the plastic industry experienced the highest average annual output growth of 7.5%, followed by professional equipment with 6.4% and non-electrical machinery with 6.1%. On the other hand, two industries with the lowest output growth were textiles with 1.6% and wood with 2.1%, both considered as traditional and labour-intensive industries. Apart from these two, average annual input growth for all industries was positive ranging from 0.1% in the industrial chemicals industry to 4.7% in plastic. TFP growth increased substantially in all industries by at least 1.9% a year with the exception of the petroleum refineries industry, which had only 0.6%. The highest annual TFP growth occurred in the beverages industry with 4.1%, followed by professional equipment with 3.2%.

Due to negative input growth, output growth for the textiles and wood industries was completely explained by TFP growth. In contrast, for the industrial chemicals and iron and steel industries TFP growth accounted for 98% and 96% of output growth, respectively. Over the 1965–98 period, the manufacturing sector's output grew by 4.8% a year, stemming from 2.5% TFP growth and 2.3% input growth. It is understood that TFP growth and input growth have respectively made comparable contributions to output growth, 52% and 48%.

5.2.3 Korea

Table 5.10 shows the average shares of industries in the Korean manufacturing sector over the period 1970–97. The textiles industry that had the highest share of 14.6% in the 1970s experienced a declining share to about 6% in the 1990s. By contrast, a number of industries, such as electric machinery, transport equipment, and non-electrical machinery, increased their shares in the manufacturing sector over time. Analogous to Japan's manufacturing sector, four major industries during the 1970–97 period were electric machinery (14.7%), transport equipment (10.2%), textiles (7.9%), and non-electrical machinery (7.4%). In general, the sum of these four dominant industries was responsible for 40% of total manufacturing output. Despite the removal of the three industries, the remaining 25 industries still accounted for nearly 92% of total manufacturing output.

Table 5.10 The average shares of individual industries in the overall manufacturing in Korea, 1970–1997 (percent)

3-digit industries	1970–79	1980–84	1985–89	1990–94	1995–97	1970–97
311 Food products	7.3	7.2	6.0	6.2	5.5	6.1
313 *Beverages*	5.5	2.9	2.2	1.8	1.5	2.2
314 *Tobacco*	6.1	5.7	3.8	2.2	1.7	2.9
321 Textiles	14.6	11.8	9.8	7.0	5.2	7.9
322 Wearing apparel	4.3	4.6	4.0	3.2	2.9	3.5
323 Leather products	0.9	0.8	1.1	1.0	0.6	0.9
324 Footwear	0.5	0.7	0.6	1.2	0.7	0.9
331 Wood products	2.6	1.1	0.8	0.9	0.8	1.0
332 Furniture	0.4	0.6	0.7	1.2	1.0	0.9
341 Paper and products	2.2	2.2	2.3	2.3	2.3	2.3
342 Printing and publishing	2.0	2.3	2.3	2.6	2.6	2.4
351 Industrial chemicals	4.8	4.6	3.7	3.7	5.0	4.3
352 Other chemicals	4.7	4.8	4.8	4.6	3.9	4.4
353 *Petroleum refineries*	5.0	4.2	2.7	2.9	3.4	3.3
354 Miscellaneous petroleum	1.0	1.0	0.7	0.4	0.2	0.5
355 Rubber products	2.7	2.7	3.1	1.5	1.1	1.8
356 Plastic products	1.4	1.9	2.5	4.0	3.3	3.1
361 Pottery, china, earthenware	0.3	0.4	0.3	0.3	0.2	0.3
362 Glass and products	0.9	0.9	0.9	1.0	1.0	1.0
369 Other non-metallic mineral	4.1	3.6	3.3	4.0	3.4	3.6
371 Iron and steel	5.6	7.0	6.1	6.0	5.3	5.9
372 Non-ferrous metals	0.9	1.2	1.2	1.1	1.2	1.1
381 Fabricated metal products	2.9	3.8	4.7	5.2	5.2	4.8
382 Non-electrical machinery	3.0	3.8	5.9	8.1	9.6	7.4
383 Electric machinery	7.9	9.7	14.3	14.5	18.1	14.7
384 Transport equipment	5.8	7.7	8.5	10.8	12.3	10.2
385 Professional equipment	0.8	0.9	1.2	0.9	1.0	1.0
390 Other manufactured	2.0	2.0	2.3	1.4	1.0	1.5

Notes and *source*: As in Table 5.6.

Table 5.11 reveals the decomposition of output growth for Korean manufacturing industries during the 1970–97 period. Korean manufacturing industries achieved outstanding performance with regard to output growth. In particular, average annual output growth of the non-electrical machinery and electric machinery industries were 20.3% and 18.9%, respectively. Moreover, double-digit output growth for Korean manufacturing industries was certainly not unusual according to Table 5.11. In spite of experiencing the lowest output growth in Korea, output of the miscellaneous petroleum industry still grew by 5.6% per annum. To some extent, the spectacular output growth in Korean manufacturing industries was attributed to the extensive use of labour and capital inputs. For instance, the plastic, non-electrical machinery and electric machinery industries had input growth of more than 14% a year. On the whole, 14 of the 25 industries experienced input growth of more than 10% per annum.

Table 5.11 Decomposition of output growth: average annual growth rates of output, input, and TFP by industry in Korea, 1970–97

3-digit industries	Output	Input	TFP
311 Food products	12.1	9.4 (78%)	2.7 (22%)
321 Textiles	9.9	5.6 (57%)	4.3 (43%)
322 Wearing apparel	13.7	9.4 (69%)	4.3 (31%)
323 Leather products	17.4	13.3 (77%)	4.1 (23%)
324 Footwear	16.4	13.6 (83%)	2.8 (17%)
331 Wood products	8.3	3.5 (42%)	4.9 (58%)
332 Furniture	17.3	14.2 (82%)	3.0 (18%)
341 Paper and products	13.6	9.6 (70%)	4.0 (30%)
342 Printing and publishing	13.3	9.1 (69%)	4.2 (31%)
351 Industrial chemicals	13.6	10.3 (75%)	3.3 (25%)
352 Other chemicals	13.2	10.4 (79%)	2.7 (21%)
354 Miscellaneous petroleum	5.6	3.1 (56%)	2.4 (44%)
355 Rubber products	11.4	7.6 (66%)	3.9 (34%)
356 Plastic products	17.5	16.1 (92%)	1.4 (8%)
361 Pottery, china, earthenware	12.9	4.6 (36%)	8.3 (64%)
362 Glass and products	13.4	10.9 (81%)	2.5 (19%)
369 Other non-metallic mineral	12.4	6.7 (54%)	5.7 (46%)
371 Iron and steel	15.1	12.0 (79%)	3.1 (21%)
372 Non-ferrous metals	16.6	10.5 (63%)	6.1 (37%)
381 Fabricated metal products	16.5	12.8 (78%)	3.7 (22%)
382 Non-electrical machinery	20.3	16.1 (79%)	4.2 (21%)
383 Electric machinery	18.9	15.4 (81%)	3.5 (19%)
384 Transport equipment	17.5	14.6 (84%)	2.8 (16%)
385 Professional equipment	17.7	12.1 (68%)	5.6 (32%)
390 Other manufactured	9.3	6.7 (71%)	2.7 (29%)
300 Manufacturing	14.5	10.9 (75%)	3.6 (25%)

Notes: 1. As in Table 5.7.
2. The final weighted growth rates for manufacturing sector does not include the tobacco, beverages and petroleum industries.

Source: As in Table 5.1.

Input growth could not completely shed light on the impressive output growth as TFP growth also played a crucial role. For example, the TFP growth of the pottery industry increased by 8.3% a year, followed by non-ferrous metals with 6.1% and other non-metallic mineral with 5.7%. With respect to the contribution of components to output growth, TFP growth accounted for 64% of output growth in the pottery industry, 58% in wood and 46% in other non-metallic mineral. Nonetheless, the contribution of TFP growth turned out to be insignificant for the plastic (8%), transport equipment (16%) and footwear (17%) industries.

Overall, output growth of the Korean manufacturing sector between 1970 and 1997 increased substantially at an average annual rate of 14.5%. In addition, input growth and TFP growth increased by 10.9% and 3.6% per annum, respectively. In terms of the contribution of components to output growth, input growth and TFP growth contributed 75% and 25%, respectively. Thus, it is obvious that the physical inputs, namely, labour and capital, remain the most important factor to explain output growth in the Korean manufacturing sector. Needless to say, the impressive TFP growth, at an average annual rate of 3.6%, also played a crucial part in shaping the success of the Korean manufacturing sector.

5.2.4 Singapore

Table 5.12 shows the average shares of individual industries in Singapore's manufacturing sector over the period 1970–97.[63] Three dominant industries with the highest share over the sample period were electric machinery with 24.4%, non-electrical machinery with 18.5% and transport equipment with 8.7%. They accounted for roughly 52% of total manufacturing output over the period 1970–97 and over 60% during the recent period of 1995–97. Given such a high share contributed by the three leading industries, it is sensible to hypothesise that the final TFP growth estimate of the overall manufacturing sector will be heavily influenced by them. Table 5.13 shows the decomposition of output growth for Singapore's manufacturing industries over the 1970–97 period. The highest average annual output growth was in the non-electrical machinery industry with 18.2%, followed by professional equipment with 15.9%, and plastic products with 11.8%. Conversely, sizeable negative output growth occurred in several traditional industries, such as wood with –2.7%, footwear with –2.0%, and rubber with –1.5%. Except for the footwear (–2.7%), wood (–2.5%) and textiles (–1.4%) industries, most industries experienced positive and substantial input growth.

[63] As mentioned earlier, three industries, tobacco, other chemicals, and petroleum refineries and miscellaneous petroleum, are not included in the sample. However, the impact of the removal has been diminishing because the total share of the three industries in manufacturing has decreased from about 20% in the 1970s to less than 13% in the 1990s.

Table 5.12 The average shares of individual industries in the overall manufacturing in Singapore, 1970–1997 (percent)

Industries	1970–79	1980–84	1985–89	1990–94	1995–97	1970–97
311 Food products	4.6	3.4	3.1	2.6	2.6	3.1
313 Beverages	1.7	1.4	1.4	1.1	0.8	1.2
314 *Tobacco*	1.1	0.8	0.6	0.6	0.2	0.6
321 Textiles	2.7	1.2	0.6	0.5	0.2	0.9
322 Wearing apparel	3.2	3.3	3.0	1.8	0.7	2.2
323 Leather products	0.2	0.1	0.1	0.1	0.1	0.1
324 Footwear	0.3	0.2	0.1	0.1	0.0	0.1
331 Wood products	3.7	1.5	0.6	0.3	0.2	1.0
332 Furniture	0.7	1.1	1.0	0.7	0.6	0.8
341 Paper and product	1.1	1.3	1.6	1.5	1.3	1.4
342 Printing and publishing	3.8	4.0	4.2	4.7	4.4	4.3
351 Industrial chemicals	1.4	1.6	5.6	3.8	1.8	3.0
352 *Other chemicals*	3.6	4.4	5.5	5.6	7.7	5.6
353+354 *Petroleum & miscel. petrol.*	15.9	14.9	6.5	7.1	5.1	8.9
355 Rubber Products	2.2	0.8	0.4	0.3	0.3	0.7
356 Plastic Products	1.5	2.0	2.2	2.8	2.5	2.3
361+362 Pottery, glass and product	0.4	0.3	0.1	0.3	0.5	0.3
369 Other non-metallic mineral	2.6	2.9	1.6	1.6	1.5	1.9
371 Iron and steel	1.7	1.3	1.0	0.7	0.4	0.9
372 Non-ferrous metals	0.3	0.3	0.3	0.3	0.1	0.3
381 Fabricated metal products	4.9	6.3	6.0	6.4	6.0	6.0
382 Non-electrical machinery	7.2	9.4	9.9	24.2	30.6	18.5
383 Electric machinery	18.6	23.9	33.8	23.0	22.7	24.4
384 Transport equipment	12.9	10.7	7.8	7.5	7.1	8.7
385 Professional equipment	1.9	1.4	1.8	1.8	2.1	1.8
390 Other manufactured products	1.4	1.3	1.3	0.7	0.5	1.0

Notes and source: As in Table 5.6.

Although average annual output growth for the Singaporean manufacturing sector between 1970 and 1997 was a remarkable performance of 9.4%, it was completely realised by employing more resources due to extraordinary average annual input growth of 10.2%. In contrast to the other East Asian manufacturing sectors, the decomposition analysis shows that TFP in Singapore actually fell by 0.8% per annum. More specifically, 12 out of 23 industries experienced TFP decline, ranging from 0.3% in the wood industry to 3.2% in electric machinery. Nonetheless, the remaining 11 industries gained positive TFP growth; in particular, the professional equipment industry achieved the largest average annual TFP growth of 3.5% over the period, followed by textiles with 1.9% and other manufactured products with 1.6%, respectively.

Table 5.13 Decomposition of output growth: average annual growth rates of output, input, and TFP by industry in Singapore, 1970–1997

Industries	Output	Input		TFP	
311 Food products	5.5	5.4	(98%)	0.1	(2%)
313 Beverages	3.7	4.7	(129%)	-1.1	(-29%)
321 Textiles	0.5	-1.4	–	1.9	–
322 Wearing apparel	3.9	4.3	(110%)	-0.4	(-10%)
323 Leather products	5.3	3.8	(72%)	1.5	(28%)
324 Footwear	-2.0	-2.7	–	0.8	–
331 Wood products	-2.7	-2.5	–	-0.3	–
332 Furniture	7.2	8.8	(123%)	-1.7	(-23%)
341 Paper and products	9.2	8.3	(90%)	0.9	(10%)
342 Printing and publishing	8.7	7.8	(90%)	0.9	(10%)
351 Industrial chemicals	9.5	9.9	(104%)	-0.4	(-4%)
355 Rubber products	-1.5	0.3	(-20%)	-1.8	(120%)
356 Plastic products	11.8	12.4	(105%)	-0.6	(-5%)
361 +362 Pottery and glass	7.0	5.9	(85%)	1.0	(15%)
369 Other non-metallic mineral	7.7	6.7	(87%)	1.0	(13%)
371 Iron and steel	3.6	6.0	(166%)	-2.4	(-66%)
372 Non-ferrous metals	2.3	4.2	(180%)	-1.9	(-80%)
381 Fabricated metal products	8.4	10.3	(122%)	-1.9	(-22%)
382 Non-electrical machinery	18.2	18.1	(99%)	0.1	(1%)
383 Electric machinery	11.1	14.3	(129%)	-3.2	(-29%)
384 Transport equipment	6.8	7.6	(111%)	-0.8	(-11%)
385 Professional equipment	15.9	12.4	(78%)	3.5	(22%)
390 Other manufactured	2.7	1.2	(43%)	1.6	(57%)
300 Manufacturing	9.4	10.2	(109%)	-0.8	(-9%)

Notes: 1. As in Table 5.7.
2. The final weighted growth rates for manufacturing sector does not include the tobacco, other chemicals and petroleum refineries and miscellaneous petroleum industries.

Source: As in Table 5.1.

Thus far, Singapore's manufacturing sector is the only sector to experience TFP decline. The theoretical interpretation of the result is that in order to maintain the same amount of output, manufacturing industries in Singapore had to utilise more resources over time. Or, given the same amount of inputs, the Singaporean manufacturers produced less output over time. Under the TFP framework, this does not imply that excess use of inputs is the cause for the technological decline, nor should this be linked with loss of knowledge or other production information (Kwong *et al.*, 2000). So, why was there TFP decline in Singapore? Wasting inputs, changes in government policy, poor management, and/or other uncontrollable factors, all could have contributed to undermining TFP growth.

Additionally, an average annual 0.8% TFP decline for Singapore's manufacturing sector is not unusual in the literature. Tsao (1985) also finds little evidence of TFP growth (0.08%) for Singapore's manufacturing industries between 1970 and 1979. The result for Singapore in this study is also consistent with Young (1995), where he suggests that Singapore's manufacturing sector experienced an average annual TFP growth rate of –1% during the 1970–90 period. He explains that manufacturing industries in Singapore always adopted the most advanced technology, which might lead to productivity loss at the outset before they efficiently managed new technology.[64] If the process of adopting new technology was continuing in Singapore over the past three decades, the full benefits of applying new technology might not be entirely realised due to the lack of a learning-by-doing effect.[65]

Thanks to the longer data set, it is possible to identify four major factors driving down TFP growth in Singapore's manufacturing sector through the above empirical analysis.[66] These can be described as follows:

1. choice of sample period,
2. inverse influence by the leading industries,
3. implementation of quality adjustment in factor inputs,
4. active government policy.

First, TFP growth for Singapore's manufacturing sector over the 1970–75 period was severely affected by external shocks, for example, the oil crisis, leading to a significant TFP decline of 5.8% as shown in Table 5.4. If this five-year period is excluded, the average annual TFP growth rate between 1975 and 1997 becomes a positive 0.4%, as shown in Table 5.14. Namely, TFP growth could be significantly raised by 1.2% per annum if the first five years were eliminated from the sample. Hence, it is believed that the choice of sample period is vital for TFP growth estimates in Singapore's manufacturing sector. This also explicitly confirms that the large variation in TFP growth

[64] This proposition has been recently examined by Huggett and Ospina (2001). They find evidence that a large investment in equipment will simultaneously reduce TFP growth by 3–9% from annual plant-level data in the Colombian manufacturing sector.

[65] Young (1992, pp.38–43) provides his bounded learning-by-doing model to reconcile the results for Singapore.

[66] A number of studies, including Tsao (1985), Toh and Low (1996), and Swee and Low (1996), have provided other interpretations behind the low estimated TFP growth for Singapore.

estimates for Singapore in the existing literature is to a large extent caused by the choice of sample period.

Table 5.14 Decomposition of output growth: average annual growth rates of output, input, and TFP by industry in Singapore, 1975–1997

Industries	Output	Input		TFP	
311 Food products	6.0	5.5	(91%)	0.5	(9%)
313 Beverages	4.6	4.4	(95%)	0.2	(5%)
321 Textiles	-2.5	-6.3	–	3.8	–
322 Wearing apparel	1.0	-0.1	(-6%)	1.1	(107%)
323 Leather products	6.5	4.1	(63%)	2.4	(37%)
324 Footwear	-3.2	-4.2	–	1.0	–
331 Wood products	-2.4	-5.6	–	3.3	–
332 Furniture	8.2	7.5	(92%)	0.7	(8%)
341 Paper and products	9.1	7.4	(81%)	1.8	(19%)
342 Printing and publishing	8.9	7.8	(87%)	1.1	(13%)
351 Industrial chemicals	9.4	8.6	(92%)	0.7	(8%)
355 Rubber products	0.6	0.3	(42%)	0.4	(58%)
356 Plastic products	11.2	9.9	(88%)	1.3	(12%)
361 +362 Pottery and glass	9.6	9.2	(96%)	0.4	(4%)
369 Other non-metallic mineral	4.6	4.8	(105%)	-0.2	(-5%)
371 Iron and steel	1.7	2.4	(142%)	-0.7	(-42%)
372 Non-ferrous metals	1.6	1.6	(103%)	0.0	(-3%)
381 Fabricated metal products	8.6	9.8	(113%)	-1.2	(-13%)
382 Non-electrical machinery	13.5	12.9	(96%)	0.6	(4%)
383 Electric machinery	9.3	10.5	(114%)	-1.3	(-14%)
384 Transport equipment	5.5	4.2	(76%)	1.3	(24%)
385 Professional equipment	7.3	2.9	(39%)	4.4	(61%)
390 Other manufactured	4.5	3.2	(72%)	1.2	(28%)
300 Manufacturing	8.5	8.1	(95%)	0.4	(5%)

Note: As in Table 5.13.
Source: As in Table 5.1.

Second, industries that experienced TFP decline and had higher shares in the manufacturing sector, such as electric machinery, fabricated metal products, and transport equipment, were likely responsible for the negative TFP growth. For example, if the average annual TFP growth (–3.2%) of the electric machinery industry with about a 25% share could be raised to zero or positive, the new TFP growth estimate would increase by 0.8 percentage points per annum for the entire manufacturing sector. That is, TFP growth will increase from –0.8% to zero or positive. Once again, the electric machinery industry and others should bear most of the responsibility for the negative TFP growth of Singapore's manufacturing sector.

Third, it is argued that the true depreciation rate of capital stock in Singapore's manufacturing sector may be higher than the figure of 0.1768 suggested by Jorgenson (1990). If the depreciation rate turned out to be higher, say, 0.20 or 0.25, the new TFP growth estimate for Singapore would certainly be higher. In addition, this study adopts the labour quality adjustment index from Young (1995), where he suggests that there was an additional annual 1.6% quality enhancement in labour input due to a growing number of better-educated workers in Singapore. If the labour quality adjustment index turned out to be lower, say, 1% or 0.5%, the new TFP growth estimate would rise again. In order to reinforce the finding of this study, the sensitivity analyses of both issues will be critically explored for Singapore's manufacturing sector in Chapter 6, section 4. Nonetheless, the sensitivity tests show that the TFP growth estimates for Singapore in this study are fairly robust unless extreme parameters are chosen. For more details on the sensitivity test, see Chapter 6, section 4.

Fourth, in contrast to Hong Kong's laissez faire policy, the Singaporean government has been actively participating in economic activities and providing many schemes, grants, and tax concessions to promote investment as documented by Huff (1999) and Ermisch and Huff (1999). Nevertheless, excess investment may result in the lower use of capacity utilisation, indicating overestimation of capital input and understatement of TFP growth in Singapore.[67] Even if the problem of low capacity utilisation did exist in Singapore, TFP growth for Singapore's manufacturing sector remained insignificant according to the results of the sensitivity test.[68]

Among the four possible causes for low TFP growth, the choice of sample period and several leading industries with large negative TFP growth are most likely to be responsible for the gloomy outcome in Singapore. Although removal of these adverse factors may moderately raise the outcome from negative to positive TFP growth, this small positive TFP growth remains incomparable with other East Asian manufacturing

[67] A recent study by Toh and Ng (2002) disagrees with this suggestion. They find that Singapore's returns to capital investment are similar to those of Hong Kong and Taiwan, suggesting that Singapore did not over-invest. Note that their investigation focuses on the entire economy, not the manufacturing sector.

[68] The issue of decreasing capacity utilisation leading to overestimation of capital input growth is similar to that of employing low depreciation rate. Thus, it can be easily examined by changing the depreciation rates as shown in Chapter 6, section 4.

sectors, which implies that the spectacular output growth in Singapore's manufacturing industries was mainly driven by factor accumulation with little progress in TFP.

5.2.5 Taiwan

Table 5.15 The average shares of individual industries in the overall manufacturing in Taiwan, 1981–1999 (percent)

Industries	1981–85	1986–90	1991–95	1996–99	1981–99
Food, beverages and tobacco	12.0	10.4	9.4	7.4	9.4
Textile mill products	8.9	7.5	5.7	4.2	6.2
Wearing apparel, accessories*	7.3	5.0	2.7	1.5	3.6
Leather, fur and products	1.7	1.6	0.8	0.5	1.0
Wood and bamboo products	1.7	1.8	1.0	0.5	1.2
Furniture and fixtures	1.2	1.5	1.5	1.3	1.4
Pulp, paper and paper products	3.4	2.9	2.0	1.7	2.3
Printing processings	1.4	1.3	1.3	1.1	1.2
Chemical material	5.7	6.1	7.1	7.4	6.7
Chemical products	1.5	1.9	2.5	2.9	2.3
Petroleum and coal products	6.5	4.7	5.1	6.0	5.5
Rubber products	1.7	1.4	1.2	1.0	1.3
Plastic products	5.6	7.1	5.7	4.7	5.7
Non-metallic mineral products	4.5	4.0	4.8	4.1	4.4
Basic metal industries	6.3	6.6	7.5	7.6	7.1
Fabricated metal products	4.2	5.2	6.4	5.6	5.5
Machinery and equipments	3.2	4.0	5.0	5.0	4.5
Electrical & electronic machinery	10.6	14.5	19.3	29.4	19.9
Transport equipments	6.9	6.7	7.2	5.6	6.5
Precision instruments	1.1	1.1	0.9	0.7	0.9
Other industrial products	4.8	4.6	2.9	2.0	3.3

Notes: 1. As in Table 5.6.
2. * denotes wearing apparel, accessories and other textile products industry.
Source: Author's calculation based on *dX* for Windows 3.0, EconData: CEIC Database, Taiwan.

Table 5.15 presents the average shares of individual industries in overall manufacturing in Taiwan between 1981 and 1999. The shares of labour-intensive industries, including textiles, leather, wearing apparel and wood industries, fell over time. Notably, the share of the wearing apparel industry in the entire manufacturing dropped drastically from 7.3% in the 1981–85 period to 1.5% in the 1996–99 period. As opposed to labour-intensive industries, the shares of capital-intensive industries in the manufacturing sector rose gradually, for instance, the electrical and electronic machinery, machinery and equipments, and chemical products industries. Recently, a fast-growing electrical and electronic machinery industry shared nearly 30% of total manufacturing output over the 1995–99 period. The petroleum and coal products industry comprised merely a 5.5% share during the 1981–99 period, implying that the remaining 20 industries still accounted for 94.5% of total manufacturing output.

Table 5.16 Decomposition of output growth: average annual growth rates of output, input, and TFP by industry in Taiwan, 1981–1999

Industries	Output	Input		TFP	
Food, beverages and tobacco	3.3	3.7	(112%)	-0.4	(-12%)
Textile mill products	1.5	3.0	(204%)	-1.5	(-104%)
Wearing apparel, accessories	-3.2	0.8	–	-3.9	–
Leather, fur and products	-0.9	4.6	–	-5.5	–
Wood and bamboo products	-1.7	-3.2	–	1.5	–
Furniture and fixtures	6.1	3.4	(56%)	2.7	(44%)
Pulp, paper & paper products	1.7	6.0	(353%)	-4.3	(-253%)
Printing processings	4.2	8.2	(194%)	-4.0	(-94%)
Chemical material	8.4	4.5	(53%)	3.9	(47%)
Chemical products	11.0	7.4	(67%)	3.6	(33%)
Rubber products	3.0	5.3	(175%)	-2.3	(-75%)
Plastic products	5.8	4.1	(71%)	1.7	(29%)
Non-metallic mineral	4.8	2.8	(59%)	2.0	(41%)
Basic metal industries	8.1	6.2	(77%)	1.9	(23%)
Fabricated metal products	7.6	9.0	(118%)	-1.3	(-18%)
Machinery and equipments	8.1	7.7	(95%)	0.4	(5%)
Electrical & electronic mach.	13.2	11.5	(87%)	1.7	(13%)
Transport equipments	4.0	6.2	(156%)	-2.2	(-56%)
Precision instruments	3.5	5.2	(147%)	-1.7	(-47%)
Other industrial products	0.9	2.5	(271%)	-1.6	(-171%)
Manufacturing	6.5	6.3	(96%)	0.2	(4%)

Notes: 1. As in Table 5.7.
2. The final weighted growth rate of manufacturing does not include the petroleum and coal products industry.

Source: As in Table 5.1.

Table 5.16 presents the decomposition of output growth in the manufacturing of Taiwan over the period 1981–99. Out of 20 industries, only three experienced negative output growth. These were wearing apparel with –3.2%, wood products with –1.7%, and leather with –0.9%. In terms of fast-growing industries, the electrical and electronic machinery, chemical products and chemical material industries had average annual output growth of 13.2%, 11.0% and 8.4%, respectively. The only industry with negative input growth was the wood products industry with –3.2% per annum. In terms of TFP growth, 11 out of 20 industries experienced negative TFP growth. It appears that labour-intensive industries were more likely to be associated with a TFP decline, such as leather with –5.5% per annum, pulp and paper with –4.3%, printing with –4.0%, and wearing apparel with –3.9%; however, the furniture (2.7%) and wood (1.5%) industries exhibited significant gains in TFP. The highest average annual TFP growth of 3.9% occurred in the chemical material industry, followed by chemical products with 3.6% and furniture with 2.7%. The electrical and electronic machinery industry with the highest share in the overall manufacturing sector gained a moderate TFP progress of 1.7%.

Comparing Table 5.15 with Table 5.16 shows that industries with increasing shares in Taiwan's manufacturing sector were always linked with significant positive TFP growth, for example, the electrical and electronic machinery, basic metal, chemical material and chemical products industries. Moreover, out of 20 industries eight with decreasing shares in manufacturing were found to have negative TFP growth. This may suggest that less productive industries in Taiwan tend to lose shares in the manufacturing sector; that is, resources (labour and capital inputs) are likely to be allocated to industries with higher productivity, such as the electrical and electronic machinery industry.

The striking result of declining TFP growth for Taiwan manufacturing industries in the 1990s warrants further discussion. According to Figure 5.6, deceleration of TFP growth took place after 1991.[69] After the Taiwanese government officially lifted the ban on indirect investment in mainland China in 1991, massive Taiwanese investment and funds flowed into the other side of the Taiwan Straits, in particular, in labour-intensive industries due to rising labour costs and increasingly strict environmental regulations. Hence, there is a good reason to speculate that the slowdown of TFP growth in Taiwan's manufacturing sector was probably initiated by this huge outward investment. Given the fact that access to low-cost resources in mainland China is no longer prohibited, Taiwanese manufacturers had little incentive to upgrade production technology, which requires a heavy investment in R&D and involves uncertainty. A sharp decline in TFP in the 1990s is therefore comprehensible (Kwong *et al.*, 2000). Due to limited data, this

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[69] Similarly, Kwong *et al.* (2000) argue that technology (or TFP) decline in Hong Kong's manufacturing industries was most likely caused by the relocation of manufacturing production to mainland China. The liberalisation in China since 1978 eliminated the need to upgrade local production technology because the rate of return to technology upgrade requiring heavy investment in R&D was uncertain.

study is not able to analyse the causes of TFP slowdown but it would be worthwhile presenting the decomposition of output growth between 1981 and 1991, which is reported in Table 5.17.

Manufacturing output and factor inputs over the 1981–91 period increased by 7.5% and 4.7% per annum, respectively, suggesting 2.8% TFP growth. Except for the wearing apparel and wood industries with small negative input growth, output growth and input growth were positive for all industries. There were only five industries exhibiting negative TFP growth during the 1981–91 period in Table 5.17 in contrast to 11 industries by 1999 in Table 5.16. A number of industries experienced remarkable TFP progress, such as the chemical material with 6.6% per annum, plastic with 6% and basic metal with 5.3%. Moreover, the finding of this study for Taiwan's manufacturing sector during the period 1981–91 is consistent with Young (1995), where he finds an average annual TFP growth rate of 2.7% over the period 1980–90.

Table 5.17 Decomposition of output growth: average annual growth rates of output, input, and TFP by industry in Taiwan, 1981–1991

Industries	Output	Input	TFP
Food, beverages and tobacco	5.2	3.7 (72%)	1.5 (28%)
Textile mill products	3.5	1.5 (41%)	2.1 (59%)
Wearing apparel, accessories	1.1	-0.5 (-45%)	1.6 (145%)
Leather, fur and products	5.5	6.9 (127%)	-1.5 (-27%)
Wood and bamboo products	3.9	-0.9 (-23%)	4.8 (123%)
Furniture and fixtures	8.1	4.9 (61%)	3.1 (39%)
Pulp, paper & paper products	2.1	5.2 (248%)	-3.1 (-148%)
Printing processings	5.4	10.2 (187%)	-4.7 (-87%)
Chemical material	9.6	3.0 (31%)	6.6 (69%)
Chemical products	12.4	7.9 (64%)	4.5 (36%)
Rubber products	5.3	4.1 (78%)	1.2 (22%)
Plastic products	9.8	3.8 (39%)	6.0 (61%)
Non-metallic mineral	6.3	1.8 (28%)	4.5 (72%)
Basic metal industries	9.3	4.0 (43%)	5.3 (57%)
Fabricated metal products	11.5	9.9 (86%)	1.7 (14%)
Machinery and equipments	10.1	6.7 (66%)	3.4 (34%)
Electrical & electronic mach.	12.6	8.5 (68%)	4.1 (32%)
Transport equipments	7.1	4.7 (66%)	2.4 (34%)
Precision instruments	7.1	7.3 (102%)	-0.1 (-2%)
Other industrial products	4.2	4.6 (109%)	-0.4 (-9%)
Manufacturing	7.5	4.7 (62%)	2.8 (38%)

Note and *source*: As in Table 5.16.

Table 5.18 Sources of output growth by industry for Hong Kong, Japan, Korea and Singapore

	Hong Kong (1976–97)			Japan (1965–98)			Korea (1970–97)			Singapore (1970–97)		
Industries	Output growth	Input growth	TFP growth	Output growth	Input growth	TFP growth	Output growth	Input growth	TFP growth	Output growth	Input growth	TFP growth
311 Food products	0.911	0.300	0.611	1.633	0.927	0.706	3.262	2.545	0.717	1.477	1.449	0.028
313 Beverages	0.537	0.345	0.192	1.629	0.263	1.367	–	–	–	0.991	1.278	-0.287
321 Textiles	-0.510	-0.998	0.488	0.533	-0.435	0.968	2.674	1.516	1.158	0.135	-0.367	0.502
322 Wearing apparel	-0.727	-1.116	0.389	1.374	0.662	0.712	3.700	2.548	1.152	1.057	1.167	-0.110
323 Leather products	-0.505	-1.366	0.861	1.080	0.252	0.827	4.697	3.603	1.094	1.425	1.019	0.406
324 Footwear	-2.851	-2.633	-0.218	1.642	0.697	0.945	4.422	3.678	0.744	-0.527	-0.736	0.209
331 Wood products	-1.163	-1.629	0.466	0.698	-0.198	0.896	2.246	0.936	1.310	-0.734	-0.664	-0.070
332 Furniture	-1.790	-2.153	0.363	1.635	0.713	0.921	4.659	3.838	0.821	1.935	2.386	-0.452
341 Paper and products	0.555	0.053	0.502	1.288	0.600	0.688	3.685	2.597	1.087	2.474	2.235	0.239
342 Printing and publishing	1.308	0.749	0.560	1.833	0.956	0.877	3.589	2.468	1.121	2.347	2.117	0.231
351 Industrial chemicals	0.460	-0.104	0.564	0.956	0.020	0.936	3.670	2.769	0.901	2.575	2.681	-0.105
352 Other chemicals	–	–	–	1.952	0.984	0.968	3.553	2.818	0.735	–	–	–
353 Petroleum refineries	–	–	–	0.867	0.668	0.199	–	–	–	–	–	–
354 Miscellaneous petroleum	–	–	–	1.249	0.460	0.789	1.502	0.841	0.661	–	–	–
355 Rubber products	-1.923	-2.614	0.690	1.370	0.586	0.783	3.087	2.043	1.044	-0.398	0.080	-0.478
356 Plastic products	-1.144	-1.776	0.632	2.479	1.565	0.914	4.736	4.345	0.390	3.180	3.336	-0.157
361 Pottery, china	0.811	-0.037	0.848	1.296	0.607	0.689	3.474	1.237	2.237	1.881	1.597	0.283
362 Glass and products	–	–	–	1.191	0.550	0.642	3.617	2.935	0.682	–	–	–
369 Other non-metallic min.	–	–	–	1.479	0.480	0.999	3.352	1.801	1.550	2.071	1.806	0.265
371 Iron and steel	-0.230	-0.568	0.338	0.948	0.041	0.908	4.086	3.244	0.842	0.967	1.608	-0.642
372 Non-ferrous metals	–	–	–	1.153	0.543	0.610	4.479	2.840	1.639	0.625	1.128	-0.504
381 Fabricated metal products	-0.378	-1.046	0.668	1.800	0.940	0.860	4.455	3.466	0.989	2.261	2.769	-0.509
382 Non-electrical machinery	1.389	0.560	0.830	2.011	1.065	0.947	5.488	4.347	1.141	4.916	4.892	0.025
383 Electric machinery	0.223	-0.751	0.974	1.967	1.350	0.617	5.111	4.153	0.958	2.991	3.858	-0.868
384 Transport equipment	0.300	-0.215	0.515	1.728	1.064	0.664	4.713	3.949	0.764	1.847	2.058	-0.211
385 Professional equipment	0.294	-0.296	0.590	2.127	1.069	1.058	4.791	3.275	1.516	4.305	3.355	0.950
390 Other manufactured	-0.035	-0.550	0.515	1.376	0.546	0.830	2.519	1.799	0.720	0.739	0.315	0.424
300 Manufacturing	-0.068	-0.642	0.574	1.589	0.761	0.828	3.908	2.932	0.976	2.526	2.748	-0.221

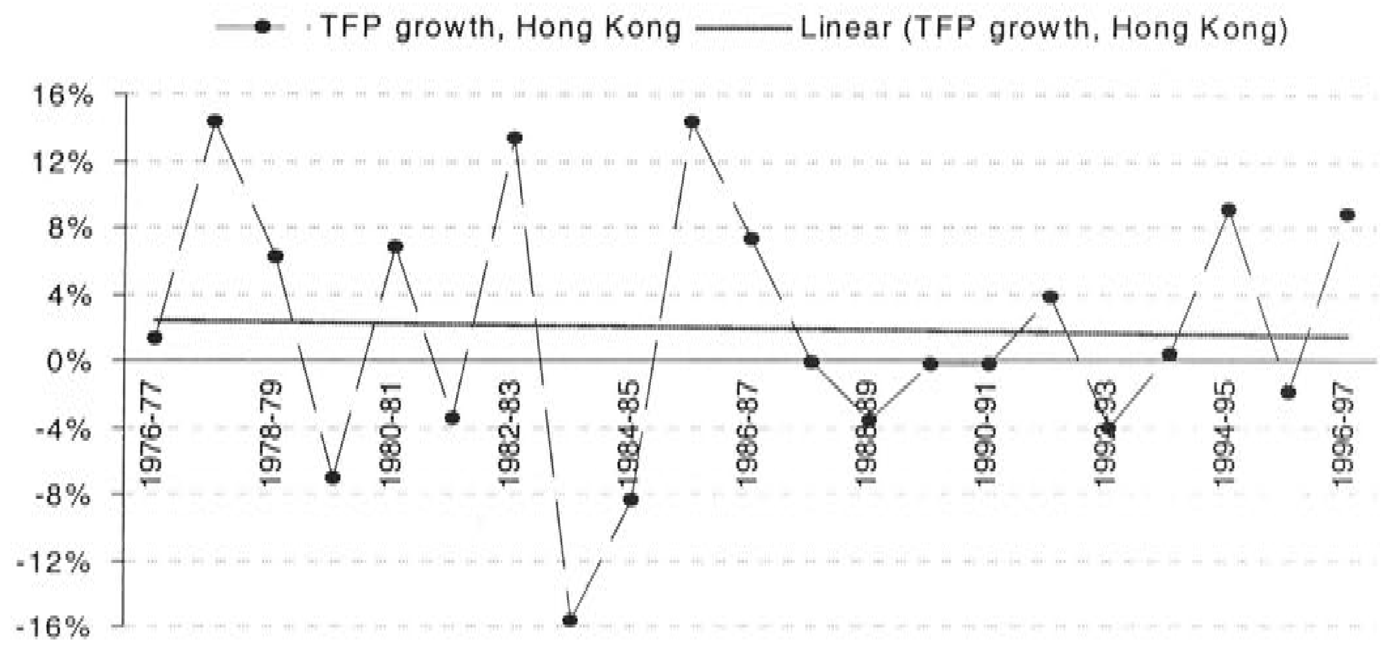
Table 5.19 Sources of output growth by industry in Taiwan

	Taiwan (1981–99)			**Taiwan (1981–91)**		
Industries	Output	Input	TFP	Output	Input	TFP
Food, beverages and tobacco	0.588	0.660	-0.072	0.520	0.374	0.146
Textile mill products	0.266	0.543	-0.277	0.354	0.145	0.209
Wearing apparel, accessories	-0.570	0.138	-0.708	0.109	-0.049	0.158
Leather, fur and products	-0.157	0.832	-0.989	0.545	0.694	-0.149
Wood and bamboo products	-0.304	-0.573	0.269	0.390	-0.091	0.481
Furniture and fixtures	1.089	0.609	0.480	0.805	0.490	0.314
Pulp, paper & paper products	0.306	1.081	-0.775	0.209	0.518	-0.309
Printing processings	0.758	1.471	-0.713	0.544	1.018	-0.474
Chemical material	1.506	0.804	0.703	0.958	0.301	0.657
Chemical products	1.973	1.323	0.650	1.236	0.792	0.445
Rubber products	0.547	0.955	-0.408	0.525	0.408	0.116
Plastic products	1.043	0.739	0.303	0.982	0.383	0.599
Non-metallic mineral	0.860	0.508	0.352	0.629	0.179	0.449
Basic metal industries	1.461	1.123	0.338	0.927	0.400	0.527
Fabricated metal products	1.371	1.613	-0.242	1.152	0.987	0.165
Machinery and equipments	1.454	1.384	0.070	1.014	0.670	0.344
Electrical and electronic mach.	2.379	2.075	0.304	1.257	0.851	0.405
Transport equipments	0.720	1.120	-0.400	0.708	0.469	0.239
Precision instruments	0.638	0.940	-0.302	0.714	0.726	-0.012
Other industrial products	0.164	0.444	-0.280	0.421	0.460	-0.039
Manufacturing	1.169	1.128	0.041	0.749	0.468	0.280

5.3 Estimates and Trends of TFP growth in the East Asian Manufacturing Sectors

This section discusses the estimates and trends of annual TFP growth for the five East Asian manufacturing sectors. Due to limited space, the annual TFP growth estimates for individual industries will not be discussed here but the details are available in Tables 5.18 to 5.22. In addition, the annual TFP growth estimates for the five manufacturing sectors in East Asia are graphed in Figures 5.1 to 5.6.[70]

Figure 5.1 Trend of annual TFP growth estimates in Hong Kong's manufacturing, 1976–1997



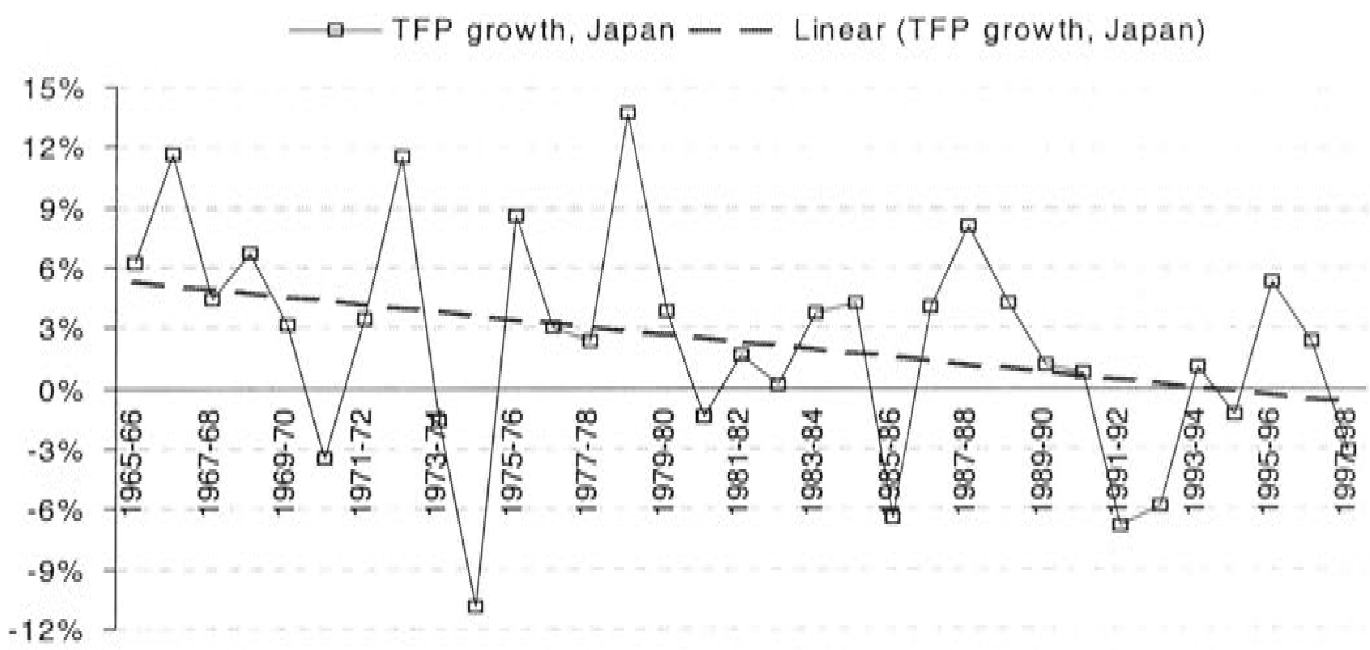
Source: The annual TFP growth estimates are available from Table 5.20.

The annual TFP growth estimates for the entire manufacturing sector in this study is computed by taking the average share of each industry in overall manufacturing in two consecutive years as a weight multiplied by the TFP growth rate of that industry. Table 5.20 shows annual TFP growth estimates for manufacturing industries in Hong Kong from 1976 to 1997. Hong Kong's manufacturing sector was in general successful in terms of achieving progress in TFP. Sizeable TFP growth occurred in 1977–78 (14.3%), 1982–83 (13.3%), and 1985–86 (14.4%) while the worst TFP performance of –15.7% was in

[70] Compared with the output growth graphs presented in Chapter 4, it is found that TFP growth and output growth in fact moved closely together. The rationale behind this outcome is not difficult to work out. As capital and labour inputs cannot be expanded or reduced considerably in a short period of time, once output growth follows the business cycle fluctuations, TFP growth will be affected by the business cycle as well.

1983–84. Regardless of the rapid relocation of manufacturing production to mainland China since the mid-1980s, Hong Kong's manufacturing sector continued to gain TFP progress in the 1990s. Despite the insignificant slowdown of TFP growth as indicated by Figure 5.1, moderate TFP growth for the manufacturing sector of Hong Kong was maintained throughout the period 1976–97.

Figure 5.2 Trend of annual TFP growth estimates in Japan's manufacturing, 1965–1998

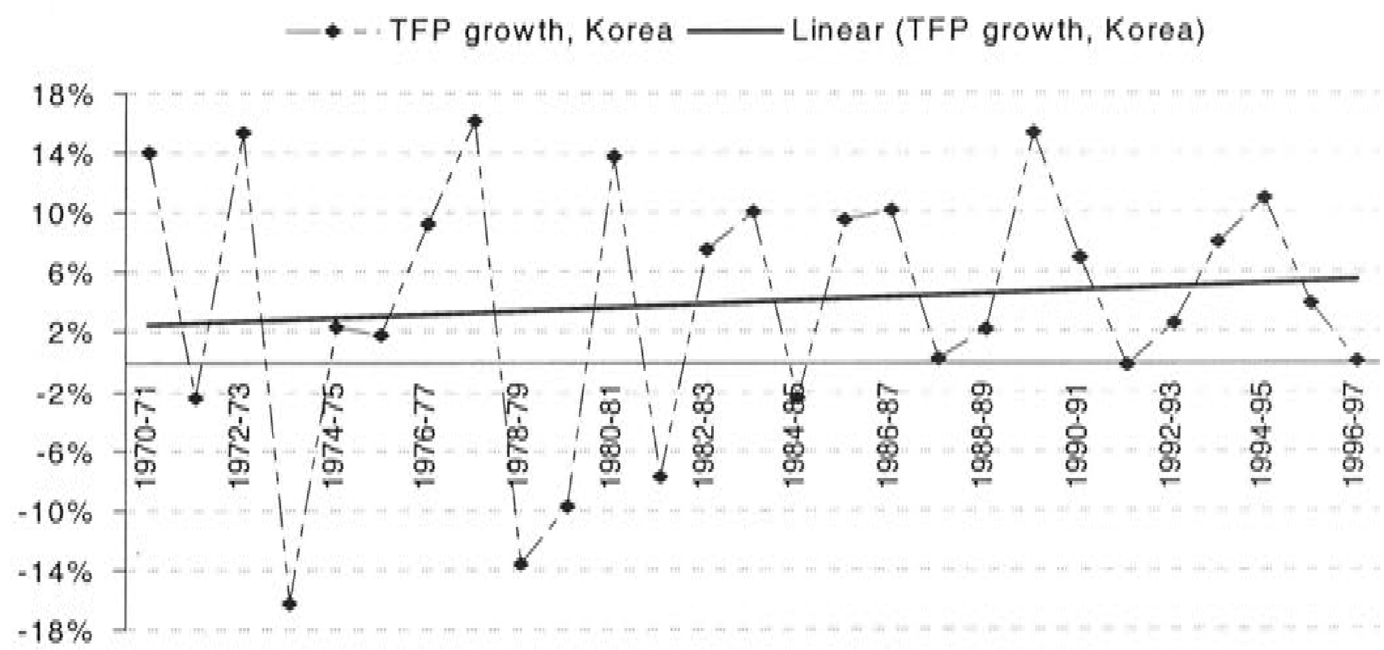


Source: The annual TFP growth estimates are available from Table 5.21.

Figure 5.2 shows the trend of annual TFP growth estimates in the manufacturing sector of Japan over the period 1965–98. The linear trend of TFP growth for the manufacturing sector was in significant decline. Table 5.21 presents annual TFP growth estimates for manufacturing industries in Japan over the 1965–1998 period. The Japanese manufacturing sector had outstanding TFP growth in the late 1960s, 1970s and 1980s. The highest TFP growth of 13.7% occurred in 1978–79 but the worst result of –10.9% was in 1974–75 due to the oil crisis of the early 1970s. Since then, TFP growth was managed at a reasonable level until 1990. Due to the economic slump of the Japanese economy in the last decade, TFP growth for the manufacturing sector was on average negative in the 1990s. To some extent, this outcome reflects the end of technological borrowing phase in post-war Japan, i.e., catching up process, which has recently been highlighted by Hayami and Ogasawara (1999).

Likewise, the TFP growth of Korean manufacturing industries was seriously affected by the two major oil crises. The 2-digit negative TFP growth rates took place in 1973–74 (–16.3%) and 1978–80 (–13.6%) and the highest TFP growth of 15.3% occurred in 1972–73 and 1989–90. In spite of the external impacts, Korean manufacturing industries during the 1970–97 period have on average gained the highest TFP growth among the five East Asian manufacturing sectors. Moreover, Figure 5.3 shows the trend of annual TFP growth estimates in the manufacturing sector of Korea over the period 1970–97. In contrast to Hong Kong and Japan, Figure 5.3 reveals that Korea's manufacturing sector has been gaining TFP growth since 1970 and shows no sign of slowing down. Table 5.22 presents annual TFP growth estimates for manufacturing industries in Korea from 1970 to 1997.

Figure 5.3 Trend of annual TFP growth estimates in Korea's manufacturing, 1970–1997

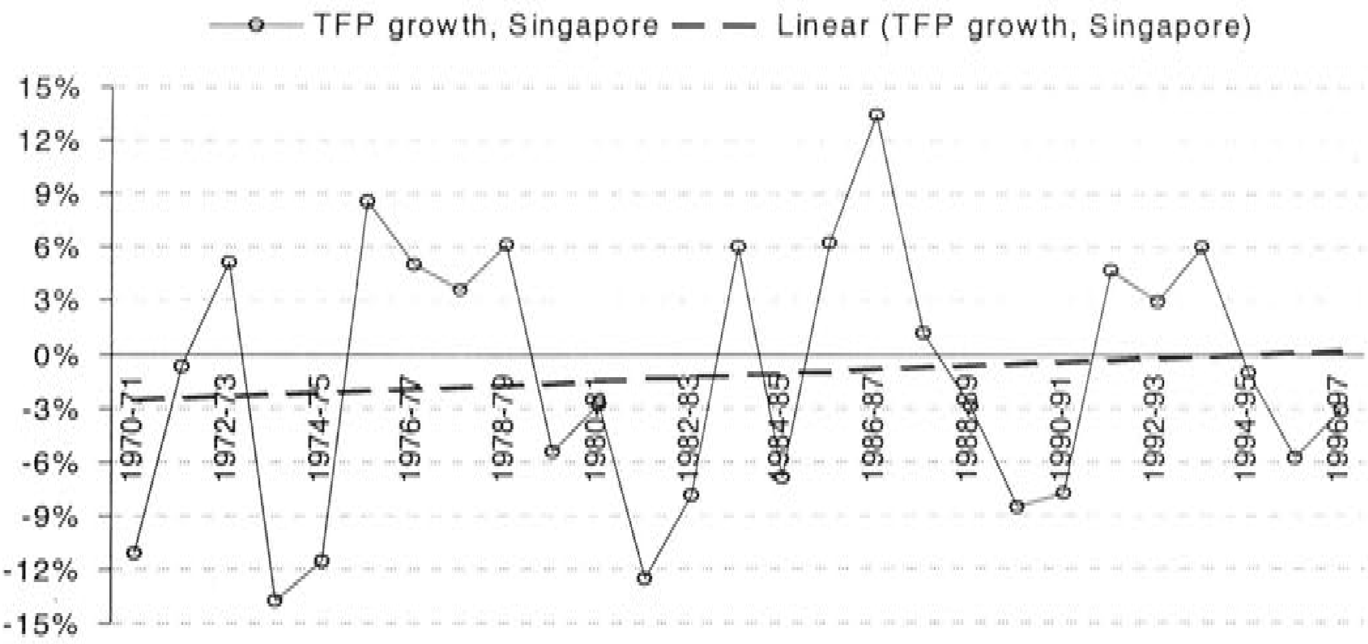


Source: The annual TFP growth estimates are available from Table 5.22.

Table 5.22 presents annual TFP growth estimates for manufacturing industries in Singapore over the 1970–1997 period. Similar to Japan and Korea, Singapore's manufacturing sector experienced significant negative TFP growth in the first half of 1970s, such as in 1973–74 (–13.8%) and 1974–75 (–11.5%). After that, considerable negative TFP growth still took place over the 1979–1983 and 1988–1991 periods. In contrast, the best TFP growth of 13.5% arrived in 1986–87 when the manufacturing sector rebounded from the economic recession in 1985. On average, TFP growth remained in negative throughout the entire period 1970–97. To reconcile the findings for

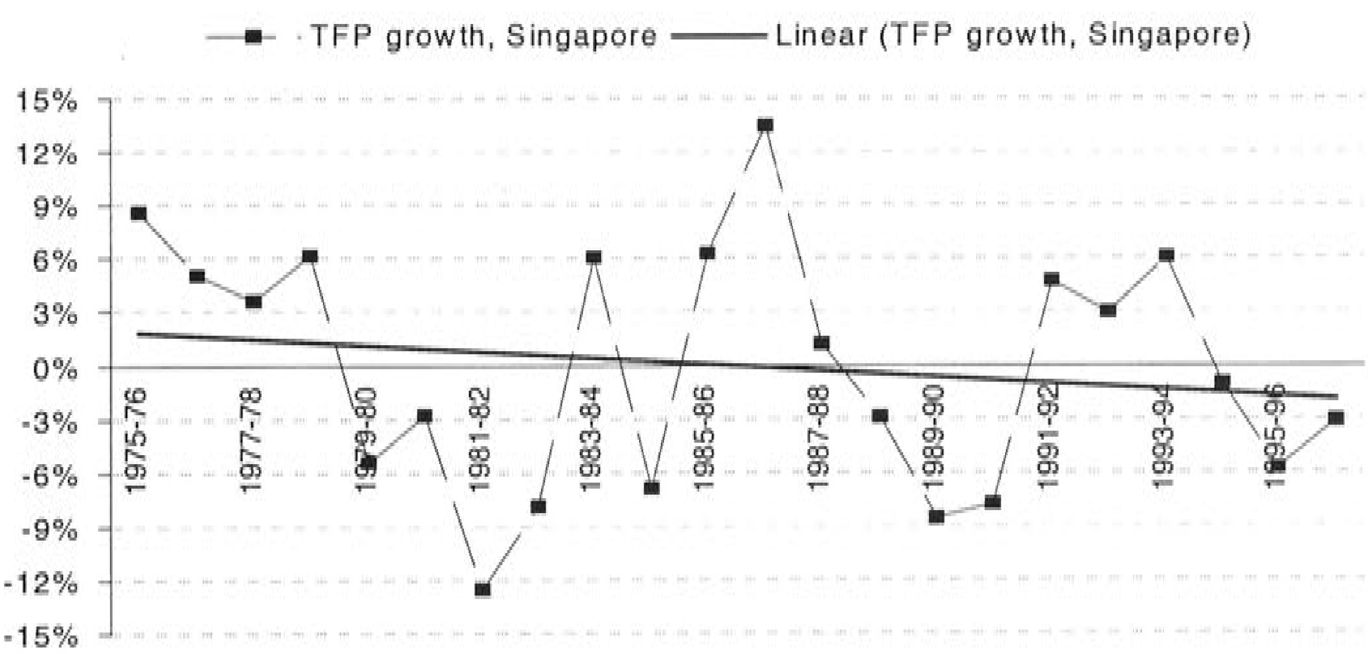
Singapore's manufacturing sector, several possible explanations have been described in section 5.2.

Figure 5.4 Trend of annual TFP growth estimates in Singapore's manufacturing, 1970–1997



Source: The annual TFP growth estimates are available from Table 5.23.

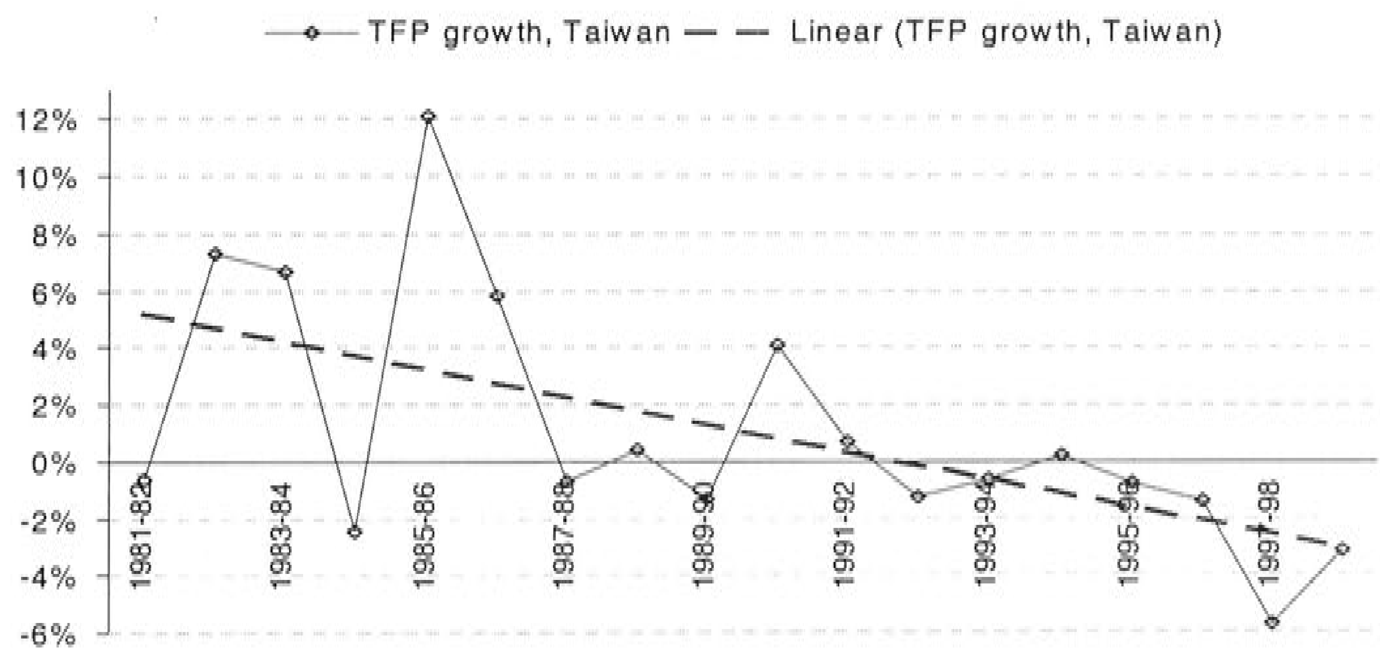
Figure 5.5 Trend of annual TFP growth estimates in Singapore's manufacturing, 1975–1997



Source: The annual TFP growth estimates are available from Table 5.23.

Figure 5.4 shows the trend of annual TFP growth estimates in the manufacturing sector of Singapore over the period 1970–97. As mentioned earlier, average annual TFP growth in Singapore during the period 1970–97 was –0.8%. Regardless of the negative TFP growth, Singapore's manufacturing sector gradually reduced the extent of TFP decline due to the upward sloping trend of TFP growth as shown in Figure 5.4. Likewise, Toh and Ng (2002) suggest that although TFP growth for the overall economy had been negligible between 1971 and 1986, according to more recent data it has improved significantly over the period 1987–96, averaging 2.6% per annum. Nevertheless, the interpretation must be cautiously carried out in the case of Singapore's manufacturing sector. Strictly speaking, the trend of TFP growth has much to do with the choice of the sample period as stressed in section 5.2. If the first half of the 1970s is excluded from the sample, the trend of TFP growth becomes downward sloping. In other words, the level of TFP deteriorated over time; see Figure 5.5.

Figure 5.6 Trend of annual TFP growth estimates in Taiwan's manufacturing, 1981–1999



Source: The estimated annual TFP growth is available from Table 5.24.

Table 5.24 presents annual TFP growth estimates for manufacturing industries in Taiwan over the 1981–1999 period. TFP in Taiwanese manufacturing industries progressed significantly in the 1980s, particularly over the 1982–84 and 1985–87 periods, but deteriorated sharply in the 1990s. The highest TFP growth of 12.1% occurred in 1985–86 and the worst of –5.7% in 1997–98, which coincided with the Asian financial crisis. On average, Taiwan's manufacturing industries achieved very small progress in TFP over the 1981–99 period.

Figure 5.6 shows the trend of annual TFP growth estimates in the manufacturing sector of Taiwan over the period 1981–99. Analogous to the Japanese manufacturing sector, the trend of TFP growth for Taiwan's manufacturing sector declined drastically, especially, in the 1990s. As declining TFP growth became more evident in the 1990s, this implies that the role of factor accumulation (or input growth) in determining output growth turned out to be more important, as opposed to the role of TFP growth.

Under the framework of growth accounting, the idea of TFP growth has often been used synonymously with technological progress in the literature. In other words, the traditional concept of treating TFP growth as technological progress or technology advance misleads the nature of technological progress and ignores the importance of technical efficiency pertaining to industry and firm's organisation and effective use of available resources. The decomposition of TFP growth and the development of technological progress versus technical efficiency change, which may be related to the structural transformation in the East Asian manufacturing sectors, are critically discussed in Chapter 6.

Table 5.20 Annual TFP growth rates by industry in Hong Kong (percent), continued

Industries	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90
311 Food products	9.1	13.2	-4.6	-7.1	8.8	15.1	6.9	-21.3	-6.3	6.0	12.9	14.9	-10.1	5.7
313 Beverages	15.8	-18.7	-0.2	-1.0	-6.0	7.6	12.2	-39.8	31.8	12.4	-18.6	33.5	-1.2	2.2
321 Textiles	-15.7	24.6	7.9	-12.7	0.5	0.5	29.6	-16.4	-1.8	24.5	3.3	-7.0	-2.2	-0.7
322 Wearing apparel	-0.1	9.8	5.2	0.4	-1.4	-3.1	10.8	-12.7	-7.4	9.9	11.8	-6.2	-3.2	-2.0
323 Leather products	15.9	22.2	6.9	-14.1	-4.4	-3.1	26.2	-23.0	-23.9	27.8	12.6	-16.1	7.2	-6.5
324 Footwear	-10.5	26.8	5.9	15.1	-15.3	-10.6	13.9	-15.5	5.5	-1.4	-7.2	11.0	0.7	-46.8
331 Wood products	6.8	19.2	-14.7	-23.4	40.8	-22.1	20.9	-36.0	-4.0	13.0	10.3	-10.5	-24.4	5.8
332 Furniture	6.1	24.8	6.5	-19.4	18.6	-10.7	3.5	-27.1	4.1	3.4	17.8	-17.7	5.3	-1.0
341 Paper and products	-4.3	29.0	0.4	-7.2	2.0	0.4	18.8	-24.9	-5.6	23.8	-4.8	-9.7	-10.0	10.3
342 Printing and publishing	9.1	12.6	9.9	-9.8	21.6	-8.5	5.1	-12.0	2.9	-4.9	13.1	7.3	-3.8	7.8
351 +352 (Chemical products)	8.9	12.1	12.1	-7.8	2.8	-7.5	17.5	-13.7	-6.2	4.5	3.3	13.3	6.6	4.0
355 Rubber products	-7.4	-2.3	27.8	-25.8	3.2	5.8	0.2	-9.7	5.5	-13.0	16.1	2.1	4.6	4.5
356 Plastic products	5.4	12.3	8.4	-12.3	9.7	-3.8	11.2	-2.5	-7.0	14.0	-11.6	9.0	-1.6	-3.3
36 Non-metal mineral products	35.9	32.2	-4.7	-12.8	7.0	-29.6	18.7	-41.1	17.3	21.4	21.0	8.6	19.0	0.9
371 +372 (Basic metals)	2.1	19.5	-9.0	-24.2	-10.9	-1.7	9.9	-26.2	-19.8	28.4	68.9	47.7	-54.7	-29.1
381 Fabricated metal products	1.7	20.9	8.7	-12.1	0.7	-9.0	15.8	-16.8	-2.7	13.2	10.2	3.4	-7.1	-1.4
382 Non-electrical machinery	-1.4	29.3	1.5	-2.2	30.8	-6.3	25.4	-26.8	-24.3	12.7	0.2	13.1	-4.4	17.3
383 Electric machinery	16.5	10.0	8.2	-4.8	20.4	-3.8	6.5	-20.5	-30.0	22.9	14.2	-7.9	-6.4	-8.8
384 Transport equipment	-1.0	-14.5	14.8	-15.3	9.5	12.0	-14.5	-2.6	-0.7	11.7	7.5	9.9	18.6	0.7
385 Professional equipment	11.4	15.8	12.1	-9.0	4.2	-9.4	18.9	-18.1	-10.1	15.2	1.8	17.7	-6.4	-0.4
390 Other manufactured	0.9	16.6	-4.4	-3.8	12.1	-3.8	12.0	-5.6	-10.5	9.9	17.3	-13.7	-4.0	-7.5
300 Manufacturing	**1.3**	**14.3**	**6.2**	**-7.1**	**6.8**	**-3.4**	**13.3**	**-15.7**	**-8.4**	**14.4**	**7.3**	**-0.1**	**-3.6**	**-0.2**

Annual TFP growth rates by industry in Hong Kong (percent)

Industries	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97
311 Food products	-4.5	0.1	-2.4	-0.7	19.1	5.0	-1.1
313 Beverages	-12.3	6.5	1.2	0.2	#	#	#
321 Textiles	-0.7	5.1	-13.4	-2.7	12.3	-1.7	11.2
322 Wearing apparel	-1.3	4.8	-5.7	-4.6	14.2	3.2	6.1
323 Leather products	-12.3	21.2	-7.4	29.7	-13.6	-15.0	26.9
324 Footwear	-2.7	-4.4	-57.8	15.5	13.1	8.9	3.3
331 Wood products	-12.6	8.8	-2.5	18.6	9.5	-21.7	25.1
332 Furniture	-3.9	-3.3	-19.3	-19.3	18.5	39.9	-22.3
341 Paper and products	5.7	3.9	1.5	-13.6	4.5	-1.9	11.6
342 Printing and publishing	-8.6	6.0	-0.7	-1.9	-13.6	9.9	4.7
351 +352 (Chemical products)	18.4	-12.7	-2.0	-0.9	1.3	14.2	-0.3
355 Rubber products	-17.3	4.0	11.3	-12.8	24.6	-5.1	8.4
356 Plastic products	-1.9	-2.1	-1.5	-10.2	23.4	-5.1	9.2
36 Non-metal mineral products	-5.8	-13.3	20.9	3.2	33.6	-113.3	84.3
371 +372 (Basic metals)	3.9	-0.2	-0.2	-14.7	38.8	-26.2	13.5
381 Fabricated metal products	3.4	2.1	4.2	0.6	1.5	-7.7	16.9
382 Non-electrical machinery	-2.8	3.1	-14.0	-0.5	17.0	3.8	1.0
383 Electric machinery	11.5	9.1	1.0	19.8	10.6	-6.7	12.0
384 Transport equipment	-3.2	4.7	0.4	-7.1	10.2	-12.3	14.2
385 Professional equipment	-2.1	3.0	-0.6	5.4	9.0	-10.5	16.8
390 Other manufactured	-1.0	5.2	0.5	1.6	2.2	-2.3	12.8
300 Manufacturing	**-0.3**	**3.9**	**-4.1**	**0.4**	**9.1**	**-1.9**	**8.8**

Notes: 1. # denotes the removal of industry due to negative capital stock in 1995 and 1996.
2. Non-metal mineral products (36) industry includes pottery, china, earthenware (361), glass and product (362), and other non-metallic mineral (369) industries.

Source: Author's calculation.

Table 5.21 Annual TFP growth rates by industry in Japan (percent), continued

3-digit industries	1965-66	1966-67	1967-68	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82
311 Food products	4.6	2.7	1.6	3.2	4.2	7.4	9.6	1.5	2.2	2.9	5.6	4.4	-0.2	6.9	0.1	-1.3	4.3
313 Beverages	10.6	9.8	1.7	8.4	7.4	8.5	2.7	1.7	-7.4	9.6	-5.8	10.5	7.8	-2.4	8.4	5.7	4.9
321 Textiles	6.2	8.8	1.3	6.0	5.3	-0.1	6.6	18.5	-19.0	-5.6	13.2	-3.4	3.4	13.7	0.1	-2.7	2.8
322 Wearing apparel	10.3	5.4	4.6	7.1	3.1	1.7	10.1	11.0	-10.9	2.2	8.9	-3.6	1.8	8.0	-1.0	-0.3	0.1
323 Leather products	-1.1	3.4	4.0	13.2	-1.8	3.8	11.5	3.9	-4.6	3.2	7.8	1.4	-1.0	9.3	-2.0	-0.7	-1.1
324 Footwear	1.6	8.6	-1.3	13.4	17.7	-6.9	15.5	7.1	7.3	-10.9	24.2	-5.1	0.2	12.1	-6.5	-4.9	1.1
331 Wood products	10.0	6.2	3.8	4.7	6.1	-6.4	15.1	25.0	-21.7	-10.7	8.1	4.9	4.4	16.6	-0.4	-13.9	4.4
332 Furniture	8.0	6.7	3.1	5.9	5.2	2.4	9.2	10.4	-3.6	-4.7	4.0	3.6	3.6	14.6	1.0	-7.7	4.4
341 Paper and product	3.7	0.3	5.4	3.9	7.3	-4.8	-0.5	14.8	16.9	-28.2	4.4	1.6	-0.8	11.1	3.5	-2.4	2.6
342 Printing and publishing	12.7	6.6	4.4	5.7	1.7	0.9	5.5	6.5	0.2	5.4	4.7	1.5	4.6	10.7	5.1	0.6	2.1
351 Industrial chemicals	4.5	17.4	3.2	11.5	-0.9	-8.1	-4.7	11.4	-0.7	-20.6	5.3	3.1	6.2	20.2	-3.8	-5.6	5.0
352 Other chemicals	5.9	8.5	4.7	11.2	3.1	5.9	-2.9	6.8	1.6	-0.9	4.7	5.5	5.5	10.6	1.6	1.1	2.1
353 Petroleum refineries	-4.6	17.0	9.7	-3.3	1.9	4.9	-7.9	18.3	12.2	-26.2	18.3	-6.2	-20.0	53.9	24.6	-16.8	8.6
354 Miscellaneous petroleum	-16.6	4.9	-6.6	20.5	2.8	8.6	-11.8	9.8	27.5	-10.3	-23.0	14.0	4.1	17.7	5.5	22.6	-23.2
355 Rubber products	6.8	10.5	-4.2	-1.3	4.3	3.4	10.2	5.9	0.7	-11.3	8.5	1.7	3.8	10.0	5.2	-5.2	0.2
356 Plastic products	13.7	10.0	11.3	10.6	1.9	2.2	8.3	15.1	3.1	-19.8	11.0	0.2	6.2	12.9	-1.1	-3.6	1.1
361 Pottery, china	0.5	7.9	3.7	8.9	4.4	0.3	3.0	6.3	4.9	2.6	1.1	7.0	-6.2	7.2	9.5	-7.3	-1.9
362 Glass and product	-4.0	19.7	5.4	8.5	-0.7	-2.3	2.2	8.2	-9.1	-14.8	27.8	3.3	-1.9	6.1	2.2	1.5	2.3
369 Other non-metallic min.	10.0	7.3	10.6	5.2	2.9	0.1	6.9	15.5	1.0	-14.6	0.8	4.8	11.4	13.8	2.8	-0.5	-2.3
371 Iron and steel	6.6	23.9	-12.1	14.4	2.2	-11.7	6.5	25.7	1.4	-30.7	10.9	-2.0	10.4	32.0	2.3	-8.5	1.1
372 Non-ferrous metals	13.5	8.6	-5.9	10.8	-4.8	-10.6	7.2	25.2	0.3	-38.3	14.9	3.0	-1.4	28.0	14.0	-15.7	-10.0
381 Fabricated metal prod.	7.8	9.4	9.3	12.4	2.6	-4.6	-3.1	10.7	1.3	-13.3	5.8	6.0	6.5	9.5	3.3	-1.0	1.5
382 Non-electrical mach.	6.9	20.3	13.3	7.8	4.3	-6.6	-3.1	10.6	5.8	-11.2	4.3	2.0	1.4	14.7	8.0	1.0	3.7
383 Electric machinery	6.3	16.0	5.8	6.5	3.8	-12.0	7.4	5.7	-5.5	-16.4	19.1	4.4	2.6	11.7	5.5	0.8	1.8
384 Transport equipment	-0.5	9.3	7.0	-4.7	3.8	-2.5	3.5	7.9	-8.8	-1.3	11.9	5.2	-7.0	8.2	4.8	5.1	-1.3
385 Professional equipment	14.0	11.3	5.4	8.3	-2.4	6.1	-1.0	8.3	7.4	-5.9	2.5	11.0	0.3	3.9	5.0	-0.9	-3.9
390 Other manufactured	7.1	6.8	5.0	8.0	1.1	-2.8	4.7	10.9	-5.0	2.5	9.0	4.5	-4.3	11.3	2.5	2.6	1.4
300 Manufacturing	**6.2**	**11.6**	**4.4**	**6.7**	**3.2**	**-3.5**	**3.4**	**11.6**	**-1.6**	**-10.9**	**8.5**	**3.0**	**2.3**	**13.7**	**3.8**	**-1.5**	**1.7**

Annual TFP growth rates by industry in Japan (percent)

3-digit industries	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98
311 Food products	1.6	2.0	4.7	-1.5	4.6	2.3	0.5	-0.9	2.5	1.4	-2.3	-7.1	-1.5	1.4	0.2	-1.3
313 Beverages	6.3	0.5	1.6	1.1	2.9	9.2	-2.7	-4.1	-1.0	-5.0	0.8	41.6	-4.6	6.5	1.5	-4.0
321 Textiles	0.7	3.0	5.0	-4.0	6.0	5.9	0.3	-1.1	1.2	-2.7	-9.0	0.7	-1.6	3.0	4.6	22.3
322 Wearing apparel	1.3	-0.5	4.6	1.4	3.2	2.7	2.2	-1.1	5.3	-4.4	-8.2	-5.4	3.0	3.0	0.0	2.2
323 Leather products	4.1	-0.3	11.6	-0.6	1.3	6.9	1.0	-1.9	2.6	-6.9	-15.5	7.7	0.1	-0.1	-8.8	26.0
324 Footwear	-2.8	-3.8	6.0	3.2	4.2	0.3	5.3	3.1	-1.3	-5.0	-9.5	24.0	7.3	0.5	0.3	-8.4
331 Wood products	2.2	-1.9	6.0	2.8	10.6	3.9	2.9	1.2	2.5	-3.7	0.5	5.0	0.8	2.4	-2.2	-5.6
332 Furniture	1.9	-1.4	6.1	-0.1	6.5	8.8	5.5	-2.3	0.5	-7.2	-8.7	14.2	-0.4	4.4	-0.8	-6.3
341 Paper and product	4.4	5.4	0.7	2.9	7.0	5.9	3.8	-3.9	-2.5	-5.0	1.5	5.9	-2.8	6.3	1.5	-4.8
342 Printing and publishing	0.0	-1.1	3.2	-1.0	2.1	3.7	2.3	-1.1	-0.9	-5.0	-4.0	-0.6	1.4	5.5	2.5	-4.8
351 Industrial chemicals	10.3	14.0	2.1	3.8	8.1	13.2	6.4	-1.9	0.0	-1.7	-7.8	-1.0	-1.5	0.2	6.0	-5.5
352 Other chemicals	4.8	-4.1	5.0	1.5	9.2	3.5	4.0	-0.7	-2.4	-3.4	-1.1	2.5	-0.4	2.9	2.4	-6.8
353 Petroleum refineries	-11.8	-4.2	-1.9	-21.1	29.9	-5.9	-15.0	-25.0	46.2	14.5	9.5	9.2	-38.2	-22.0	-30.2	-0.7
354 Miscellaneous petroleum	-12.3	-8.5	-1.4	12.0	1.5	2.1	20.2	-1.1	0.2	3.1	3.6	2.1	-6.1	11.5	-3.0	0.8
355 Rubber products	3.1	1.4	6.3	-4.6	8.7	5.5	-0.4	5.8	-0.3	-2.6	-8.8	0.9	-2.6	6.7	7.7	-6.4
356 Plastic products	4.5	5.0	3.1	-5.0	2.5	3.4	3.0	-1.1	3.5	-5.8	-6.3	-0.6	-6.0	4.0	2.3	-2.4
361 Pottery, china	2.8	3.2	-7.8	-8.5	4.0	7.4	0.3	-2.2	1.4	-2.3	-1.3	7.9	0.3	2.2	3.9	-3.7
362 Glass and product	6.5	4.1	4.1	-14.4	7.3	10.9	5.2	-5.6	-9.2	-8.2	-5.6	10.4	-15.1	6.5	6.6	-2.9
369 Other non-metallic min.	0.9	1.6	4.8	2.4	8.7	8.8	2.4	1.8	3.1	-3.1	-2.8	2.9	-5.2	4.0	-0.3	-8.2
371 Iron and steel	-14.2	14.9	8.6	-16.8	10.2	22.9	7.3	1.1	2.9	-9.3	-10.8	-5.9	-5.3	4.8	9.5	-6.5
372 Non-ferrous metals	-5.3	12.1	-5.8	-8.4	4.9	19.1	7.1	0.0	-3.6	-7.0	-5.4	1.0	-4.0	9.0	4.4	-2.3
381 Fabricated metal prod.	-1.1	2.5	10.2	-3.5	4.0	8.6	2.9	3.8	3.9	-6.0	-8.7	1.6	-1.0	5.3	-1.1	-5.0
382 Non-electrical machinery	-4.7	5.5	5.9	-8.6	-2.1	13.0	7.5	4.9	0.6	-13.9	-12.7	4.6	0.2	8.5	2.1	-3.3
383 Electric machinery	1.4	6.1	-3.4	-13.4	-0.3	8.4	3.4	0.7	1.2	-13.3	-4.3	-3.5	2.0	5.4	3.4	-2.7
384 Transport equipment	3.0	-0.3	10.4	-12.9	5.3	6.0	7.9	5.2	-4.8	-5.4	-5.3	-2.0	0.3	10.5	3.8	-2.7
385 Professional equipment	1.6	-0.7	9.6	-9.5	-8.5	8.2	4.9	1.2	0.5	-9.6	-5.0	24.6	4.5	10.5	5.6	-2.2
390 Other manufactured	5.2	3.3	3.4	-3.8	3.6	1.8	5.3	3.0	5.0	-1.8	-6.8	1.7	-4.2	2.5	1.2	-7.0
300 Manufacturing	**0.2**	**3.7**	**4.3**	**-6.5**	**4.0**	**8.1**	**4.2**	**1.1**	**0.8**	**-6.8**	**-5.9**	**1.1**	**-1.3**	**5.3**	**2.3**	**-3.1**

Source: See Table 5.20.

Table 5.22 Annual TFP growth rates by industry in Korea (percent), continued

3-digit industries	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85
311 Food products	17.0	-18.1	-23.3	-28.1	37.2	13.5	19.1	10.0	-18.8	0.8	7.6	-1.7	0.4	-1.6	-2.8
321 Textiles	12.5	15.1	19.2	-31.1	11.8	6.3	-6.4	21.1	-10.1	-4.2	15.7	-14.3	4.9	15.4	2.7
322 Wearing apparel	14.0	-6.1	7.5	-19.1	-5.6	9.5	-3.8	18.1	-11.5	1.5	22.2	-17.2	2.0	12.8	-7.6
323 Leather products	28.4	-4.3	81.6	-27.2	12.6	-55.1	-24.1	42.5	-28.0	-17.6	47.4	-29.0	1.2	11.2	6.1
324 Footwear	-17.0	-26.3	33.1	1.2	-2.5	13.2	23.0	6.1	-21.7	-13.4	13.8	1.7	15.0	3.5	-0.7
331 Wood products	44.4	-4.6	25.0	-29.6	-13.4	-1.8	11.2	29.3	-34.0	-37.8	5.0	30.5	-4.1	-1.3	-4.9
332 Furniture	10.0	6.8	-15.7	10.3	-4.0	36.0	22.4	52.5	-33.7	-41.8	8.1	-3.7	19.8	7.6	-5.3
341 Paper and products	14.5	-1.6	34.2	-24.3	-15.4	11.5	22.2	12.6	-19.4	-5.3	13.2	-9.2	19.1	2.8	-2.9
342 Printing and publishing	24.8	-19.2	-18.1	19.5	3.4	-5.9	27.7	21.6	-4.5	-10.1	5.1	5.3	15.6	2.8	-12.5
351 Industrial chemicals	2.8	-0.1	-7.8	4.5	7.5	-12.3	10.2	16.6	-13.1	14.6	0.6	-22.6	12.0	11.1	0.7
352 Other chemicals	20.1	-8.0	1.4	0.5	10.6	6.0	10.3	11.9	-15.6	-2.4	1.3	-0.3	7.8	1.4	-5.1
354 Miscellaneous petroleum	53.6	-6.4	46.4	-67.8	5.2	-11.4	14.2	11.2	32.7	3.5	18.5	-14.8	0.3	0.2	9.8
355 Rubber products	8.1	-9.2	3.3	-7.0	1.5	14.6	3.9	16.3	4.8	-19.2	-2.8	-18.3	4.7	20.3	6.6
356 Plastic products	1.9	41.2	-1.3	-49.0	-50.0	17.2	27.0	31.0	13.8	-27.3	7.4	-16.9	18.5	20.0	-8.4
361 Pottery, china, earthenware	11.4	21.4	39.2	-23.8	12.9	25.2	48.3	31.9	7.5	-10.4	11.3	-19.4	17.2	1.2	-1.9
362 Glass and products	-18.4	-3.2	5.0	21.1	20.1	-5.8	22.3	14.1	-18.9	-18.6	-5.8	-16.8	13.2	14.4	2.7
369 Other non-metallic mineral	24.8	5.9	18.5	-4.6	24.8	-7.1	14.8	2.6	2.4	-1.7	2.6	-23.2	24.3	4.3	-2.9
371 Iron and steel	16.7	1.9	43.2	-13.6	-18.6	-12.4	-2.7	26.4	-0.5	-29.3	29.0	-2.5	-11.3	13.7	1.5
372 Non-ferrous metals	39.0	-16.2	55.7	-10.2	-9.9	9.6	38.4	19.2	-24.0	15.3	-21.2	-24.1	25.6	5.3	0.1
381 Fabricated metal products	-5.7	-4.4	30.2	11.0	-20.5	-2.0	23.6	35.2	-25.3	-33.6	26.6	-2.0	-1.1	1.5	2.0
382 Non-electrical machinery	10.6	-2.2	42.6	-20.0	-2.5	10.1	-3.2	21.1	-18.1	-37.1	14.4	-8.9	21.0	14.4	1.2
383 Electric machinery	6.9	-1.8	20.6	-3.1	-16.2	-13.7	8.6	15.5	-18.9	-10.8	20.7	-2.1	17.0	18.5	-13.7
384 Transport equipment	4.4	-23.4	30.3	-23.0	-10.3	20.4	39.6	-7.9	-34.0	-8.3	24.0	2.9	7.5	8.8	0.8
385 Professional equipment	-4.0	37.0	32.6	-29.5	30.0	8.3	-23.3	16.8	-6.1	-6.6	-4.3	-6.4	0.5	23.6	-5.3
390 Other manufactured	-10.7	-26.9	23.9	-6.2	10.8	6.2	-0.4	15.8	-13.9	-1.6	22.3	-7.8	5.0	-0.4	-2.4
300 Manufacturing	**14.0**	**-2.5**	**15.3**	**-16.3**	**2.4**	**1.7**	**9.2**	**16.1**	**-13.6**	**-9.8**	**13.7**	**-7.8**	**7.5**	**10.0**	**-2.5**

Annual TFP growth rates by industry in Korea (percent)

3-digit industries	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97
311 Food products	4.5	4.9	0.4	9.2	17.4	10.8	7.2	3.5	0.3	3.8	7.8	2.3
321 Textiles	12.5	12.3	-3.5	-5.2	0.3	16.2	9.8	0.8	3.0	5.7	6.4	2.8
322 Wearing apparel	11.3	12.4	1.9	2.7	9.3	7.1	1.3	21.6	7.0	15.2	2.0	2.3
323 Leather products	19.8	17.0	-7.1	-2.3	22.9	-0.7	11.6	-2.1	14.2	-13.2	6.8	-4.1
324 Footwear	9.1	6.0	7.7	1.2	21.5	34.2	-17.3	-16.3	-3.5	-1.7	28.2	-11.7
331 Wood products	6.6	17.2	13.1	12.0	25.2	26.3	-8.5	9.3	4.5	5.9	3.8	5.6
332 Furniture	-0.3	11.8	15.8	9.4	20.5	23.0	-77.1	-3.0	19.7	2.1	11.2	3.4
341 Paper and products	10.2	10.7	-1.1	-2.4	7.9	13.0	2.3	-2.9	10.7	7.9	5.2	-0.2
342 Printing and publishing	3.7	13.7	2.4	7.5	20.0	-7.4	4.4	12.3	1.9	6.9	9.2	-6.5
351 Industrial chemicals	4.9	7.9	0.1	-1.8	25.4	-7.2	-5.5	-0.6	2.8	22.6	23.4	4.7
352 Other chemicals	-2.5	19.9	-4.3	6.5	11.1	-3.5	-7.6	12.0	0.6	-7.1	9.8	7.3
354 Miscellaneous petroleum	3.2	-1.8	-3.5	1.5	-1.8	-3.0	14.1	2.9	-15.6	-9.7	-4.5	-5.9
355 Rubber products	12.2	11.1	2.5	-4.0	10.5	15.7	8.0	-0.6	7.5	7.3	18.1	-10.1
356 Plastic products	0.9	9.7	8.3	-6.1	11.3	26.9	10.4	-11.8	13.0	12.5	-46.6	2.6
361 Pottery, china, earthenware	7.2	11.2	-2.8	6.9	8.0	1.3	1.8	12.3	-0.4	4.6	6.5	1.8
362 Glass and products	7.2	-8.1	3.7	-0.7	35.0	11.4	0.0	-5.8	16.4	11.4	-3.5	-2.8
369 Other non-metallic mineral	8.6	8.2	9.2	10.6	19.0	15.7	-9.8	-1.0	-1.1	11.6	6.9	2.2
371 Iron and steel	8.6	15.1	-9.1	8.2	19.9	6.4	0.9	-1.7	13.1	10.2	-2.7	0.2
372 Non-ferrous metals	14.9	19.3	7.6	-4.1	7.3	13.9	-8.1	-5.2	6.5	25.3	-10.1	9.3
381 Fabricated metal products	15.4	14.0	7.3	5.9	13.1	-1.7	4.0	3.9	12.3	-2.5	13.7	-5.1
382 Non-electrical machinery	18.0	10.0	8.5	3.7	16.3	12.8	-6.7	0.4	3.5	10.6	10.1	3.7
383 Electric machinery	12.3	6.0	-0.5	0.1	13.9	-0.8	0.0	12.9	18.2	26.2	0.0	-13.6
384 Transport equipment	3.9	6.0	-6.1	3.5	28.7	6.5	2.8	-4.9	7.1	6.1	4.3	11.8
385 Professional equipment	18.1	10.4	11.4	-1.9	7.5	-9.6	9.4	1.0	16.4	11.4	6.3	2.7
390 Other manufactured	23.7	14.1	-3.2	-2.4	7.1	1.8	3.5	5.7	6.4	10.6	-0.7	-1.3
300 Manufacturing	**9.4**	**10.1**	**0.2**	**2.2**	**15.3**	**7.0**	**-0.2**	**2.6**	**8.0**	**11.0**	**3.9**	**0.1**

Source: See Table 5.20.

Table 5.23 Annual TFP growth rates by industry in Singapore (percent), continued

Industries	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85
311 Food products	2.1	-4.1	11.6	-14.8	-1.7	4.4	18.5	-3.4	-6.5	-14.2	18.4	-18.7	-3.7	-2.4	-6.3
313 Beverages	-10.3	-21.9	-0.3	-11.3	10.8	12.5	3.7	-0.7	-3.3	-1.5	8.7	-3.5	-13.5	-5.7	-10.2
321 Textiles	4.9	10.2	26.6	-50.0	-22.5	34.6	-2.3	10.9	15.0	-1.3	-19.7	-10.8	5.2	-0.3	-5.4
322 Wearing apparel	1.0	10.7	-16.9	-19.6	-5.8	33.6	8.1	12.6	-5.9	-3.9	0.5	-0.6	-3.7	5.7	-10.8
323 Leather products	-3.5	24.5	13.5	-9.4	-37.5	53.6	8.0	-16.2	-15.9	-12.6	-12.1	2.3	-24.0	8.3	-4.3
324 Footwear	21.2	-7.0	-31.4	-6.7	24.7	5.5	-22.9	10.7	16.0	-26.1	-12.2	-18.0	6.2	0.1	-24.9
331 Wood products	-24.1	-16.9	33.3	-53.9	-14.3	54.6	12.0	13.6	-4.4	-41.7	1.8	-17.1	6.3	-5.6	-6.5
332 Furniture	-9.2	-9.4	1.7	-44.2	4.1	23.1	-1.3	-0.6	-16.0	5.1	5.7	-7.0	-6.1	9.7	-6.5
341 Paper and products	5.2	9.0	18.2	-22.1	-22.9	17.3	9.8	4.9	14.5	3.4	-28.1	-16.5	9.1	10.3	11.3
342 Printing and publishing	-13.5	18.6	-1.0	0.7	-5.4	8.7	11.8	0.9	-11.0	-5.5	7.9	-9.6	1.1	-3.3	-8.9
351 Industrial chemicals	-3.5	8.3	20.5	-29.6	-18.5	15.4	12.5	-2.5	11.6	-3.5	-7.4	-10.4	-24.8	46.0	-5.4
355 Rubber products	-4.4	-35.4	40.2	-18.6	-35.6	33.1	-8.0	-3.0	55.6	-55.1	-14.0	-2.6	-1.8	-31.5	-27.9
356 Plastic products	7.5	3.3	-4.7	-21.2	-25.6	10.7	21.1	6.7	11.4	-9.6	-4.6	-8.6	-6.5	5.9	-3.9
361 +362 Pottery, Glass	-11.0	-4.3	21.6	2.2	7.8	12.6	29.2	23.8	0.2	-51.5	-16.3	-23.9	11.6	6.7	-62.5
369 Other non-metallic mineral	11.2	-2.8	38.0	-10.7	-0.4	-11.4	5.6	-8.0	16.6	10.7	23.5	-1.9	-18.9	-45.9	-17.3
371 Iron and steel	-39.8	25.4	37.7	22.1	-87.8	1.8	27.7	33.6	11.2	4.8	-11.0	2.3	-31.6	-25.3	-25.9
372 Non-ferrous metals	-6.9	-59.2	34.5	-0.7	-4.0	-4.3	32.3	4.1	36.4	-14.3	12.2	-37.7	11.1	14.4	-24.3
381 Fabricated metal products	-22.1	-0.7	12.9	-10.9	-1.5	-1.1	6.1	3.4	4.6	-10.6	-7.2	2.8	-12.0	-6.8	-17.1
382 Non-electrical machinery	1.2	17.9	4.4	-20.9	-3.7	-12.4	-4.4	-5.0	9.4	0.9	23.7	-24.2	-27.7	-3.7	-5.4
383 Electric machinery	-27.4	4.5	-4.2	-16.4	-11.8	7.8	1.1	3.1	2.2	-9.1	-16.2	-9.8	4.7	23.0	-15.3
384 Transport equipment	-14.6	-8.2	-13.2	10.3	-16.4	8.6	6.0	0.5	17.4	10.1	-4.1	-22.8	-19.7	2.8	6.9
385 Professional equipment	33.1	10.3	-30.6	-20.3	16.9	-4.6	-0.7	27.8	-7.6	4.9	-24.1	4.5	-4.9	27.5	24.5
390 Other manufactured products	5.6	0.5	3.2	8.4	-3.9	23.1	5.7	16.9	20.7	-9.8	-11.0	-26.8	2.9	-11.1	3.4
300 Manufacturing	**-11.2**	**-0.7**	**5.1**	**-13.8**	**-11.5**	**8.6**	**5.0**	**3.6**	**6.2**	**-5.4**	**-2.8**	**-12.5**	**-8.0**	**6.0**	**-9.1**

Annual TFP growth rates by industry in Singapore (percent)

Industries	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97
311 Food products	2.6	11.4	8.4	4.8	-1.6	-5.6	-6.6	-6.0	7.3	-5.4	14.3	-3.1
313 Beverages	4.1	9.9	7.7	-34.8	-31.2	-11.4	12.8	9.7	15.6	4.3	1.2	10.5
321 Textiles	32.7	26.5	-0.2	-2.5	6.2	-9.5	-0.3	-0.6	10.1	-9.7	-6.9	15.4
322 Wearing apparel	6.4	23.5	-1.5	-6.5	-3.8	-11.2	-4.3	-9.9	-3.5	-10.0	-0.6	2.8
323 Leather products	6.8	19.6	26.4	9.0	-11.5	-9.4	1.9	-12.3	-0.6	3.7	-4.5	26.8
324 Footwear	5.1	17.8	1.2	26.0	14.7	-23.2	9.4	12.9	3.8	4.4	19.4	-13.2
331 Wood products	1.0	12.5	25.3	14.5	-6.4	-14.1	6.1	7.7	8.5	5.6	-6.0	2.3
332 Furniture	-6.7	-11.6	9.6	7.1	-2.4	-0.8	13.0	3.1	-3.6	4.0	-1.5	-6.7
341 Paper and products	3.5	18.3	-2.2	1.7	6.9	-10.6	-9.3	3.3	2.9	-5.6	-1.4	-4.7
342 Printing and publishing	-5.6	10.6	5.7	3.1	2.3	-4.5	7.2	1.9	8.7	-2.1	-3.4	2.4
351 Industrial chemicals	24.6	50.7	38.4	-22.9	-35.8	-17.2	-20.4	-0.8	-0.7	-38.4	-13.2	10.7
355 Rubber products	15.3	28.9	-0.7	-5.7	-4.9	8.3	5.7	-2.3	5.5	12.5	-5.1	-0.6
356 Plastic products	2.8	20.2	1.4	9.1	-4.3	-6.0	-0.8	7.0	3.2	-7.1	-7.1	-5.5
361 +362 Pottery, Glass	-33.2	20.6	13.2	69.1	-39.9	8.5	38.6	4.4	16.9	14.3	-34.0	-2.0
369 Other non-metallic mineral	-24.5	-0.1	-0.7	17.7	21.1	28.5	10.9	-1.2	3.9	7.0	-7.8	-17.0
371 Iron and steel	25.3	26.3	9.0	6.5	-25.0	-13.1	11.6	-37.1	-9.5	2.2	-8.3	12.5
372 Non-ferrous metals	9.3	23.4	4.7	-4.6	10.5	-21.6	14.6	-6.9	-5.4	-49.5	-3.7	-8.7
381 Fabricated metal products	9.5	10.7	5.5	4.1	-1.2	-0.5	7.0	-2.4	-2.6	-3.1	-9.7	-6.7
382 Non-electrical machinery	-8.0	2.6	7.1	100.1	-17.7	-14.3	3.2	6.4	3.9	1.0	0.5	-7.3
383 Electric machinery	8.3	10.6	-10.6	-45.7	-4.2	-1.6	8.8	6.9	14.7	6.2	-16.4	-8.8
384 Transport equipment	12.5	11.7	15.7	-4.8	-0.9	-15.1	9.2	-5.7	0.0	-17.3	-2.9	25.3
385 Professional equipment	15.8	7.6	5.2	-2.5	-3.5	-14.0	15.3	12.1	5.4	4.9	6.1	4.0
390 Other manufactured products	19.2	24.2	-16.1	-19.1	2.0	-7.7	-3.4	-6.3	1.9	9.0	-11.2	16.9
300 Manufacturing	**6.3**	**13.5**	**1.1**	**-2.9**	**-8.6**	**-7.9**	**4.7**	**3.0**	**6.1**	**-1.1**	**-5.8**	**-3.1**

Source: See Table 5.20.

Table 5.24 Annual TFP growth rates by industry in Taiwan (percent)

Industries	1981-82	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99
Food, beverages & tobacco	1.0	11.0	1.4	2.0	0.6	7.9	-0.3	-2.2	-2.3	-2.2	2.1	-2.8	-0.6	-2.8	-1.0	-9.2	3.1	0.8
Textile mill products	-6.1	1.5	7.3	-0.7	17.1	2.2	-9.9	4.7	-2.0	7.7	-2.9	-8.4	0.3	-4.9	-3.8	-0.3	-6.7	-8.6
Wearing apparel, access.	13.4	-3.7	7.8	-13.9	7.4	5.6	-11.6	4.3	3.4	3.4	-6.4	-11.2	-23.3	-6.6	4.0	2.5	-6.2	-30.7
Leather, fur and products	3.7	-5.3	5.3	-1.6	8.5	-8.4	-8.5	-2.5	-2.2	3.5	-19.2	-5.3	-4.6	-12.1	3.8	-10.1	-8.6	-9.0
Wood and bamboo	-3.6	7.2	14.8	11.4	24.9	9.8	-12.8	-5.4	-13.3	15.2	9.9	5.8	-13.3	-7.4	0.8	6.3	-6.5	-9.1
Furniture and fixtures	-14.7	4.6	6.6	-9.4	23.0	7.7	7.2	8.3	-8.5	10.9	9.7	1.9	2.3	2.9	12.4	3.9	-5.1	1.9
Pulp, paper and paper	-8.4	2.7	6.5	-2.4	14.1	0.7	-11.3	-6.7	-12.7	-10.4	-10.6	-11.6	-1.3	-1.4	-7.0	0.5	-4.9	1.0
Printing processings	-19.1	-1.2	4.0	-12.2	8.9	-3.3	0.2	-6.9	-3.9	-6.1	3.5	-4.6	-6.4	-4.6	-6.6	3.3	10.3	-6.7
Chemical material	6.6	18.9	17.1	5.9	15.1	-0.5	-1.0	-1.8	1.5	6.0	4.9	3.6	10.2	-1.3	-1.3	1.5	-3.2	-4.9
Chemical products	8.1	8.0	15.0	6.8	17.3	4.5	-4.3	-11.0	1.5	2.8	6.7	6.6	3.2	4.1	6.5	10.1	-0.1	-1.5
Rubber products	4.7	3.9	-4.7	0.5	4.4	4.4	-0.5	-5.6	6.7	2.4	6.0	-4.8	-7.5	-4.6	-6.2	-9.8	-7.6	-4.1
Plastic products	4.6	8.9	8.7	6.1	23.4	7.3	2.3	-0.9	-2.0	4.9	-0.8	2.8	0.7	-5.6	6.2	-0.5	-15.7	-3.1
Non-metallic mineral	-7.0	9.0	2.4	2.7	3.1	9.7	9.1	7.4	5.5	4.3	4.6	0.8	1.7	3.2	-1.2	-0.8	-1.7	-6.9
Basic metal industries	0.2	14.7	12.2	-0.9	15.2	0.3	2.4	1.5	5.9	6.0	-0.8	0.0	-7.3	-9.5	-4.4	10.1	-0.9	1.8
Fabricated metal products	-12.7	6.7	6.0	-0.6	11.7	1.2	3.3	-0.5	-1.0	9.9	-0.6	-7.8	-2.7	-0.4	-7.1	-3.0	-7.4	0.1
Machinery and equipments	-11.7	13.0	4.6	2.3	13.9	11.9	7.3	-3.7	-2.0	3.7	2.1	-1.6	-0.7	2.2	-1.5	-7.9	-10.3	1.2
Electrical & electronic	1.1	10.2	9.8	-9.0	15.6	9.1	2.6	1.1	-1.4	7.5	0.4	5.4	4.3	9.4	2.6	-2.7	-8.6	-2.3
Transport equipments	1.4	1.7	1.0	-12.8	10.1	16.2	-1.8	10.9	-2.0	2.7	1.6	-9.8	-8.0	-4.2	-12.2	-5.1	-3.6	-12.3
Precision instruments	10.4	19.2	-6.0	-14.7	4.0	4.2	4.1	0.5	-10.0	-6.4	-2.6	-3.1	-0.6	-1.7	-3.9	-6.9	-8.7	8.8
Other industrial products	-5.1	8.5	4.9	-6.3	9.6	6.2	1.8	-6.1	-9.1	-3.2	2.0	-1.2	-5.5	2.4	7.9	-0.6	-11.8	-6.8
Manufacturing	**-0.6**	**7.3**	**6.7**	**-2.4**	**12.1**	**5.8**	**-0.7**	**0.4**	**-1.3**	**4.1**	**0.7**	**-1.3**	**-0.7**	**0.2**	**-0.8**	**-1.4**	**-5.7**	**-3.1**

Source: See Table 5.20.

Chapter 6

6 SOURCES OF TFP GROWTH

According to the model outlined in Chapter 3, the potential production frontier is constructed using the estimated frontier coefficients shown in Tables 4.2 to 4.6. Taking actual labour and capital inputs into the potential production frontier, potential output can be obtained. The actual output of each industry is then compared with potential frontier output. Given the same level of input, the closer to frontier output, the higher the technical efficiency. Given unchanged inputs, the larger the shift in production frontier, the higher the technological progress. Applying these definitions, the focus of this chapter is to identify sources of TFP growth and distinguish TFP growth from technological progress.

Following Nishimizu and Page (1982), TFP growth is decomposed into contributions due to technological progress and technical efficiency change, which explicitly distinguishes TFP growth from technological progress. Section 6.1 discusses the decomposition of TFP growth for the five East Asian manufacturing industries. Section 6.2 analyses the long-term trends of technical efficiency change and technological progress and provides empirical evidence with regard to structural transformation across East Asian manufacturing sectors. For instance, since the early 1990s technical efficiency improvement has gradually replaced the role of technological progress in Japan. Section 6.3 examines two hypotheses for high-tech and low-tech industries, respectively. First, the productivity growth of high-tech industries is compared with that of low-tech to examine whether high-tech industries have higher TFP growth. Second, the hypothesis is carefully examined that the sources of TFP growth for high-tech industries come largely from technological progress and for low-tech industries mainly from technical efficiency improvement. To consolidate the findings of this study, section 6.4 performs a series of sensitivity tests for Singapore's manufacturing industries using various capital depreciation rates and labour quality adjustment indices. The comparison with earlier TFP studies is then carried out for the five East Asian manufacturing industries in section 6.5.

6.1 Sources of TFP Growth: Technological Progress versus Technical Efficiency

In the growth accounting framework, TFP growth has often been used synonymously in the literature with technological progress. The traditional approach of treating TFP growth as technological progress not only misleads the nature of technology advance but also ignores a learning-by-doing effect, and the importance of technical efficiency pertaining to effective use of available resources. Put differently, the decomposition of output growth employed in growth accounting neither elucidates the real causes of growth nor evaluates industrial policy and government regulation. This is undoubtedly impractical because TFP growth explicitly captures technological progress as well as reflects an improvement in using available resources and technology. Following Nishimizu and Page (1982), who incorporate the concept of technical inefficiency into the production process, this study decomposes TFP growth into technological progress and technical efficiency change for the five East Asian manufacturing sectors, respectively.

6.1.1 Hong Kong

Table 6.1 presents the decomposition of TFP growth for Hong Kong's manufacturing industries over the period 1976–97. With the exception of the footwear industry (–1.0%), all industries experienced positive TFP growth, ranging from 0.9% a year in the beverages industry to 4.6% in electric machinery. Apart from the non-metal mineral products industry (–0.3%), all industries gained technological progress, from 0.1% in the chemical products industry to 3.8% in wearing apparel on an average annual basis. Surprisingly, the highest technological progress occurred in the wearing apparel industry, which is considered to be traditional and labour-intensive. Some of the labour-intensive industries, such as wood, furniture, and textiles, also experienced substantial technological progress. One possible interpretation is that since the production of low-end products in Hong Kong has gradually been relocated to mainland China, the only way to sustain the higher labour costs is to upgrade production technology, which would allow the production of high-end products to survive competitively in international markets.

Table 6.1 Sources of TFP growth: technological progress and technical efficiency change in Hong Kong's manufacturing industries, 1976–97

Industries	TFP growth	Tech. progress		TE change	
311 Food products	2.9	1.6	(54%)	1.3	(46%)
313 Beverages	0.9	0.9	(102%)	0.0	(-2%)
321 Textiles	2.3	2.4	(102%)	-0.1	(-2%)
322 Wearing apparel	1.9	3.8	(207%)	-2.0	(-107%)
323 Leather products	4.1	1.5	(37%)	2.6	(63%)
324 Footwear	-1.0	2.2	–	-3.2	–
331 Wood products	2.2	2.3	(106%)	-0.1	(-6%)
332 Furniture	1.7	2.2	(128%)	-0.5	(-28%)
341 Paper and products	2.4	1.7	(72%)	0.7	(28%)
342 Printing and publishing	2.7	1.7	(65%)	0.9	(35%)
351 +352 (Chemical products)	2.7	0.1	(4%)	2.6	(96%)
355 Rubber products	3.3	1.7	(50%)	1.6	(50%)
356 Plastic products	3.0	2.5	(84%)	0.5	(16%)
36 Non-metal mineral products	4.0	-0.3	(-7%)	4.3	(107%)
371 +372 (Basic metals)	1.6	0.9	(59%)	0.7	(41%)
381 Fabricated metal products	3.2	2.8	(87%)	0.4	(13%)
382 Non-electrical machinery	4.0	1.9	(48%)	2.1	(52%)
383 Electric machinery	4.6	2.7	(58%)	1.9	(42%)
384 Transport equipment	2.5	2.1	(84%)	0.4	(16%)
385 Professional equipment	2.8	1.7	(60%)	1.1	(40%)
390 Other manufactured products	2.5	2.5	(101%)	0.0	(-1%)
300 Manufacturing	2.7	2.5	(90%)	0.2	(10%)

Notes: 1. Due to rounding, figures above may not add up.
2. Figures in percentage point in parenthesis are the contribution to output growth. The relative contributions are calculated based on the entire sample period, *not* annual estimates.
3. Non-metal mineral products (36) industry includes pottery, china, earthenware (361), glass and product (362), and other non-metallic mineral (369) industries.
4. The final outcomes for the manufacturing sector exclude the tobacco industry and subsequently, beverages (1995–97) and footwear (1993–97).

Source: Author's calculation.

Among 21 industries, six experienced technical efficiency deterioration, especially, wearing apparel with –2.0% a year and footwear with –3.2%. Yet, the non-metal mineral products industry enjoyed the highest average annual technical efficiency improvement of 4.3% on an average annual basis, followed by chemical and leather products with about 2.6%. On examining contributions to TFP growth, technological progress completely accounted for TFP growth in a number of industries, such as furniture, and wearing apparel. Interestingly, technological progress shows up as the major contributor to TFP growth in several labour-intensive industries, including textiles, furniture, wood and wearing apparel. However, technical efficiency improvement also played a significant role; for example, it was fully responsible for TFP growth in the non-metal mineral industry.

On average, the manufacturing sector gained 2.7% annual TFP growth stemming from 2.5% technological progress and only 0.2% technical efficiency improvement. In contrast to technical efficiency improvement, the large technological progress stands out as a dominant contributor to TFP growth.

6.1.2 Japan

Table 6.2 presents the decomposition of TFP growth for Japan's manufacturing industries over the period 1965–98. Apart from the petroleum refineries industry, manufacturing industries in Japan experienced substantial TFP growth. The highest average annual TFP growth occurred in the beverages industry with 4.1%, followed by professional equipment with 3.2% and other non-metallic mineral with 3.0%. All industries gained considerable technological progress, on an average annual basis, ranging from 2.5% in the petroleum refineries industry to 3.7% in textiles, wearing and wood. On the other hand, except for the beverages industry with 0.9% annual technical efficiency improvement, technical efficiency deteriorated across industries, ranging from 0.2% in the professional equipment industry to 1.9% in petroleum refineries. With the exception of the beverages industry, TFP growth for all industries can be completely accounted for by technological progress.

The sweeping negative technical efficiency change and positive technological progress across Japan's 27 manufacturing industries is comprehensible analytically. In practice, it always takes some time to be in full control of new technology. This implies firms will not benefit completely from the latest technology at the beginning unless they manage it thoroughly. While using plant-level data from the Colombian manufacturing sector, a recent example by Huggett and Ospina (2001) suggests that TFP initially declines after adopting new technology due to a fall in the level of technical efficiency. If there is no new technology upgrade in progress, it may recover or exceed the previous technical efficiency level some time later. However, continuous technology upgrade implies that due to lack of a learning-by-doing effect technical efficiency would not be improved.

Table 6.2 Sources of TFP growth: technological progress and technical efficiency change in Japan's manufacturing industries, 1965–1998

3-digit industries	TFP growth	Tech. progress	TE change
311 Food products	2.1	3.6 (170%)	-1.5 (-70%)
313 Beverages	4.1	3.2 (78%)	0.9 (22%)
321 Textiles	2.9	3.7 (128%)	-0.8 (-28%)
322 Wearing apparel	2.2	3.7 (172%)	-1.6 (-72%)
323 Leather products	2.5	3.4 (135%)	-0.9 (-35%)
324 Footwear	2.9	3.3 (114%)	-0.4 (-14%)
331 Wood products	2.7	3.7 (136%)	-1.0 (-36%)
332 Furniture	2.8	3.6 (128%)	-0.8 (-28%)
341 Paper and products	2.1	3.4 (162%)	-1.3 (-62%)
342 Printing and publishing	2.7	3.5 (133%)	-0.9 (-33%)
351 Industrial chemicals	2.8	3.1 (110%)	-0.3 (-10%)
352 Other chemicals	2.9	3.3 (113%)	-0.4 (-13%)
353 Petroleum refineries	0.6	2.5 (420%)	-1.9 (-320%)
354 Miscellaneous petroleum	2.4	2.9 (123%)	-0.5 (-23%)
355 Rubber products	2.4	3.4 (143%)	-1.0 (-43%)
356 Plastic products	2.8	3.3 (120%)	-0.6 (-20%)
361 Pottery, china, earthenware	2.1	3.5 (170%)	-1.5 (-70%)
362 Glass and products	1.9	3.2 (164%)	-1.2 (-64%)
369 Other non-metallic mineral	3.0	3.3 (110%)	-0.3 (-10%)
371 Iron and steel	2.8	3.2 (118%)	-0.5 (-18%)
372 Non-ferrous metals	1.8	3.2 (171%)	-1.3 (-71%)
381 Fabricated metal products	2.6	3.6 (139%)	-1.0 (-39%)
382 Non-electrical machinery	2.9	3.6 (125%)	-0.7 (-25%)
383 Electric machinery	1.9	3.6 (194%)	-1.8 (-94%)
384 Transport equipment	2.0	3.5 (174%)	-1.5 (-74%)
385 Professional equipment	3.2	3.4 (106%)	-0.2 (-6%)
390 Other manufactured products	2.5	3.6 (141%)	-1.0 (-41%)
300 Manufacturing	2.5	3.5 (139%)	-1.0 (-39%)

Notes: 1. Due to rounding, figures above may not add up.
2. Figures in percentage point in parenthesis are the contribution to output growth. The relative contributions are calculated based on the entire sample period, *not* annual estimates.
3. The final outcomes for the manufacturing sector exclude the tobacco industry.

Source: See Table 6.1.

6.1.3 Korea

Table 5.11 presents the decomposition of TFP growth for Korea's manufacturing industries over the period 1970–97. All industries increased TFP growth significantly by at least 1.4% a year. The results of TFP growth decomposition indicate that sizable technological progress was widespread across Korean manufacturing industries over time. The range of technological progress on an average annual basis was from 1.1% in the other manufactured products industry to 4.6% in non-ferrous metals. Of 25 industries, 21 exhibit technical efficiency improvement and four technical efficiency deterioration. More specifically, apart from the plastic industry (–1.2%), technical efficiency deterioration in the other three industries was negligible.

Table 6.3 Sources of TFP growth: technological progress and technical efficiency change in Korea's manufacturing industries, 1970–1997

3-digit industries	TFP growth	Tech. progress		TE change	
311 Food products	2.7	2.0	(76%)	0.6	(24%)
321 Textiles	4.3	2.3	(53%)	2.0	(47%)
322 Wearing apparel	4.3	1.3	(31%)	2.9	(69%)
323 Leather products	4.1	2.5	(62%)	1.5	(38%)
324 Footwear	2.8	2.4	(88%)	0.3	(13%)
331 Wood products	4.9	2.9	(59%)	2.0	(41%)
332 Furniture	3.0	1.9	(62%)	1.1	(38%)
341 Paper and products	4.0	3.4	(83%)	0.7	(17%)
342 Printing and publishing	4.2	2.2	(53%)	1.9	(47%)
351 Industrial chemicals	3.3	3.6	(108%)	-0.2	(-8%)
352 Other chemicals	2.7	2.5	(93%)	0.2	(7%)
354 Miscellaneous petroleum	2.4	2.6	(106%)	-0.2	(-6%)
355 Rubber products	3.9	2.3	(60%)	1.6	(40%)
356 Plastic products	1.4	2.7	(185%)	-1.2	(-85%)
361 Pottery, china, earthenware	8.3	3.9	(47%)	4.4	(53%)
362 Glass and products	2.5	2.6	(103%)	-0.1	(-3%)
369 Other non-metallic mineral	5.7	4.2	(73%)	1.6	(27%)
371 Iron and steel	3.1	2.8	(91%)	0.3	(9%)
372 Non-ferrous metals	6.1	4.6	(76%)	1.5	(24%)
381 Fabricated metal products	3.7	1.9	(51%)	1.8	(49%)
382 Non-electrical machinery	4.2	2.1	(50%)	2.1	(50%)
383 Electric machinery	3.5	2.4	(68%)	1.1	(32%)
384 Transport equipment	2.8	2.7	(95%)	0.1	(5%)
385 Professional equipment	5.6	3.2	(57%)	2.4	(43%)
390 Other manufactured products	2.7	1.1	(41%)	1.6	(59%)
300 Manufacturing	3.6	2.5	(70%)	1.1	(30%)

Notes: 1. Due to rounding, figures above may not add up.
2. Figures in percentage point in parenthesis are the contribution to output growth. The relative contributions are calculated based on the entire sample period, *not* annual estimates.
3. The final results for the manufacturing sector do not the tobacco, beverages and petroleum industries.

Source: See Table 6.1.

The decomposition result for the Korean manufacturing sector as a whole indicates average annual technological progress of 2.5% was the major contributor to TFP growth, compared with technical efficiency improvement of 1.1%, where the former accounted for about 70% of TFP growth. Hence, to some extent, technological progress represented by the adoption of new technology has been more important for raising TFP growth in the Korean manufacturing sector. Nonetheless, for some industries, such as wearing apparel, and other manufactured products, technical efficiency improvement played a more important role than technological progress in achieving TFP growth.

In theory, how can technical efficiency improvement and technological progress coexist? One possible interpretation is that Korean manufacturing industries not only continuously upgraded production technology through imported technology, innovation, or technological diffusion, but also managed to master the new technology in a short period of time. This implies that regardless of a small fall in technical efficiency at the outset, Korean industries soon caught up or even exceeded earlier levels of technical efficiency. Another possibility is that inefficient firms were not able to survive after structural and industrial reforms designed by the Korean government; hence, the aggregation of existing efficient firms has to some extent raised the level of technical efficiency for the Korean manufacturing sector as a whole. Unlike Japan, the considerable technical efficiency improvement in Korean manufacturing industries may be a result of sufficient investment in education and job-training programs, learning-by-doing effects of workers and firms, and technology spillovers within firms and industries. Other factors, including effective management, and government policy, may have also facilitated Korean industries gaining technical efficiency improvement faster.

In contrast to tangible technology, which induces technological progress, technical efficiency improvement caused by a learning-by-doing effect may be interpreted as intangible or *efficiency-based* technology. To some extent, this decomposition analysis reveals that Korean manufacturing industries have outperformed other nations in terms of applying both tangible and intangible technology.

6.1.4 Singapore

Table 6.4 presents the decomposition of TFP growth for Singapore's manufacturing industries over the period 1970–97. Note that, due to prevalent negative TFP growth and technological progress, it is not meaningful to discuss the percentage contribution of the components to TFP growth. As expected, Singapore's manufacturing industries are often regarded as a pioneer in adopting advanced technology and machinery; thus, capital stock is likely to depreciate more than the other manufacturing sectors in East Asia. This means that the growth rate of capital stock could be overestimated in Singapore resulting in understatement of TFP growth. However, the problem of overestimating capital input growth has been avoided in this study because a higher capital depreciation rate of 0.1768 (instead of 0.0925) is applied only for Singapore's manufacturing industries.

Table 6.4 Sources of TFP growth: technological progress and technical efficiency change in Singapore's manufacturing industries, 1970–1997

Industries	TFP growth	Tech. progress	TE change
311 Food products	0.1	-1.2	1.3
313 Beverages	-1.1	-1.1	0.0
321 Textiles	1.9	-1.1	3.0
322 Wearing apparel	-0.4	-0.9	0.5
323 Leather products	1.5	-1.0	2.5
324 Footwear	0.8	-0.9	1.7
331 Wood products	-0.3	-1.1	0.8
332 Furniture	-1.7	-1.0	-0.7
341 Paper and products	0.9	-1.1	2.0
342 Printing and publishing	0.9	-1.1	2.0
351 Industrial chemicals	-0.4	-1.4	1.0
355 Rubber products	-1.8	-1.0	-0.7
356 Plastic products	-0.6	-1.1	0.5
361 +362 Pottery and glass product	1.0	-1.1	2.2
369 Other non-metallic mineral	1.0	-1.1	2.1
371 Iron and steel	-2.4	-1.2	-1.2
372 Non-ferrous metals	-1.9	-1.2	-0.7
381 Fabricated metal products	-1.9	-1.1	-0.8
382 Non-electrical machinery	0.1	-1.0	1.1
383 Electric machinery	-3.2	-1.0	-2.2
384 Transport equipment	-0.8	-1.1	0.3
385 Professional equipment	3.5	-1.2	4.7
390 Other manufactured products	1.6	-1.1	2.7
300 Manufacturing	-0.8	-1.1	0.3

Notes: 1. Due to rounding, figures above may not add up.
2. Figures in percentage point in parenthesis are the contribution to output growth. The relative contributions are calculated based on the entire sample period, *not* annual estimates.
3. The final results for the manufacturing sector do not include tobacco, other chemicals and petroleum refineries and miscellaneous petroleum industries.

Source: See Table 6.1.

Even so, Singapore's manufacturing sector is the only one experiencing negative TFP growth due entirely to technological decline. Regardless of eleven industries with positive TFP growth, the entire manufacturing sector still experienced a 0.8% TFP decline on an average annual basis. As for technological progress, all 23 industries uniformly experienced negative technological progress, varying from 0.9% per annum in the wearing apparel and footwear industries to 1.4% in industrial chemicals. In terms of technical efficiency change, there were only six industries with technical efficiency deterioration, especially, the electric machinery industry with the highest technical efficiency decline of 2.2% a year. By contrast, the professional equipment industry enjoyed the highest technical efficiency improvement of 4.7% per annum, followed by textiles with 3.0% and other manufactured products with 2.7%, respectively.

As stressed earlier, in spite of negative technological progress, TFP growth can still be obtained through large technical efficiency improvement. Among individual industries, the professional equipment industry achieved the largest average annual TFP growth rate of 3.5% owing to substantial technical efficiency improvement, followed by textiles with 1.9% and other manufactured products with 1.6%, respectively. Lastly, the decomposition of TFP growth for the manufacturing sector shows that technical efficiency improved by only 0.3% a year but the level of technology declined by 1.1%, resulting in negative TFP growth in Singapore. On analysing the contribution of the components to TFP growth, considerable technological decline was the main cause for the negative TFP growth, which was a result of significant technological decline over the 1970–75 period due mainly to the oil crisis.[71]

6.1.5 Taiwan

Table 6.5 presents the decomposition of TFP growth for Taiwan's manufacturing industries over the period 1981–99. Examination of the contributions of the components to TFP growth is omitted for a number of industries due to negative TFP growth. There were nine industries gaining TFP growth and eleven experiencing negative TFP growth. The highest average annual TFP growth was in the chemical industry with 3.9%, and the worst TFP performance in the leather industry with –5.5%.

Apart from the precision instruments industry, Table 6.5 reveals that industries with negative TFP growth were always connected with technical efficiency deterioration, such

[71] Instead of blaming technological decline, if the 1970–75 period is excluded, this study suggests that technical efficiency deterioration was the main cause of low TFP growth in Singapore over the 1975–97 period. This outcome is consistent with the finding of Mahadevan and Kalirajan (2000).

as the food, textiles, wearing apparel and leather. Not surprisingly, there were several industries enjoying both technical efficiency improvement and technological progress, such as the non-metallic mineral, and electrical and electronic machinery. For the furniture, wood, machinery equipments industries, TFP growth was entire attributed to technical efficiency improvement. With respect to the overall manufacturing sector, TFP merely increased by 0.4% a year stemming from 0.8% technological progress and –0.4% technical efficiency change.

Table 6.5 Sources of TFP growth: technological progress and technical efficiency change in Taiwan's manufacturing industries, 1981–1999

Industries	TFP growth	Tech. progress		TE change	
Food, beverages and tobacco	-0.7	1.5	–	-2.2	–
Textile mill products	-2.8	2.5	–	-5.2	–
Wearing apparel, accessories*	-7.1	-2.0	–	-5.1	–
Leather, fur and products	-9.9	-5.0	–	-4.9	–
Wood and bamboo products	2.7	-1.3	(-48%)	4.0	(148%)
Furniture and fixtures	4.8	-3.6	(-75%)	8.4	(175%)
Pulp, paper and paper products	-7.8	0.1	–	-7.8	–
Printing processings	-7.1	-3.2	–	-4.0	–
Chemical material	7.0	3.3	(47%)	3.7	(53%)
Chemical products	6.5	-1.4	(-21%)	7.9	(121%)
Rubber products	-4.1	-2.6	–	-1.5	–
Plastic products	3.0	1.4	(46%)	1.6	(54%)
Non-metallic mineral products	3.5	1.0	(29%)	2.5	(71%)
Basic metal industries	3.4	2.6	(76%)	0.8	(24%)
Fabricated metal products	-2.4	-0.4	–	-2.0	–
Machinery and equipments	0.7	-0.9	(-130%)	1.6	(230%)
Electrical & electronic machinery	3.0	1.5	(50%)	1.5	(50%)
Transport equipments	-4.0	0.7	–	-4.6	–
Precision instruments	-3.0	-3.4	–	0.4	–
Other industrial products	-2.8	-1.6	–	-1.2	–
Manufacturing	0.4	0.8	(195%)	-0.4	(-95%)

Notes: 1. Due to rounding, figures above may not add up.
2. Figures in percentage point in parenthesis are the contribution to output growth. The relative contributions are calculated based on the entire sample period, *not* annual estimates.
3. The final results for the manufacturing sector do not include the petroleum and coal products industry.
4. * denotes industry of wearing apparel, accessories and other textile products.

Source: See Table 6.1.

Corresponding to the analysis for Taiwan in Chapter 5, the decomposition of TFP growth for Taiwan's manufacturing industries over the 1981–91 period is also presented in Table 6.6. The average annual TFP growth rate of 2.8% for the manufacturing sector came from 1.0% technological progress and 1.8% technical efficiency change. In terms of relative contribution to TFP growth, the former accounted for 38% of TFP growth and the latter 62%. Unlike Japan and Korea, technological progress in Taiwan during the 1981–91 period played a relatively minor role in the process of TFP growth; that is, except for the food, textiles, and electrical and electronic machinery industries, technical efficiency improvement was the major source to raise TFP growth in Taiwan. Thus, the comparison between Tables 6.5 and 6.6 indicates that the significant technical efficiency deterioration over the 1991–99 period was responsible for the slowdown of TFP growth in Taiwan's manufacturing sector. Due to the rapid changes in economic environment, such as appreciation of the New Taiwanese dollar, rising wages and environmental issues in the 1990s, a number of labour-intensive industries had no choice but to relocate overseas. The closure of firms in labour-intensive industries indicated by diminishing shares in manufacturing implies that learning-by-doing effects cannot be maintained leading to a substantial fall in technical efficiency, particularly, in labour-intensive industries.

Table 6.6 Sources of TFP growth: technological progress and technical efficiency change in Taiwan's manufacturing industries, 1981–1991

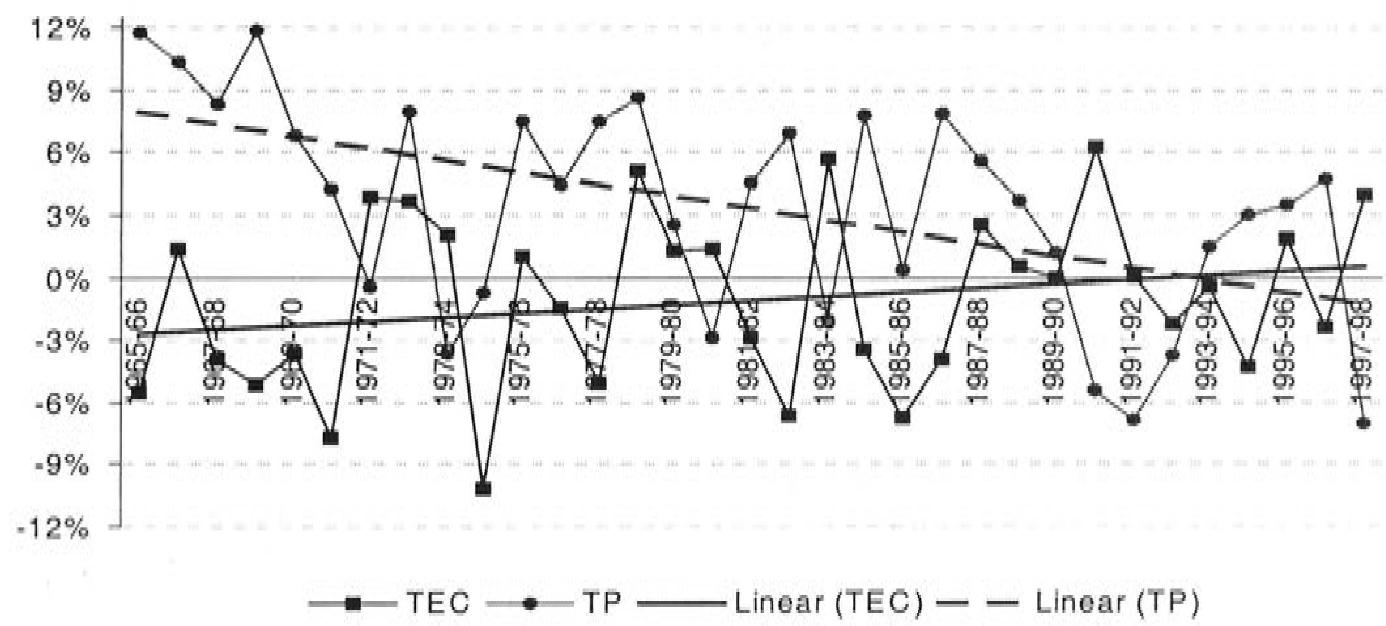
Industries (1981–1991)	TFP growth	Tech. progress		TE change	
Food, beverages and tobacco	1.5	1.4	(98%)	0.0	(2%)
Textile mill products	2.1	2.4	(112%)	-0.3	(-12%)
Wearing apparel, accessories*	1.6	0.5	(30%)	1.1	(70%)
Leather, fur and products	-1.5	-2.1	–	0.6	–
Wood and bamboo products	4.8	-0.2	(-4%)	5.0	(104%)
Furniture and fixtures	3.1	-1.4	(-43%)	4.5	(143%)
Pulp, paper and paper products	-3.1	0.0	–	-3.1	–
Printing processings	-4.7	-1.8	–	-2.9	–
Chemical material	6.6	1.4	(21%)	5.2	(79%)
Chemical products	4.5	-0.7	(-16%)	5.2	(116%)
Rubber products	1.2	-1.1	(-97%)	2.3	(197%)
Plastic products	6.0	1.9	(31%)	4.1	(69%)
Non-metallic mineral products	4.5	1.1	(24%)	3.4	(76%)
Basic metal industries	5.3	1.4	(26%)	3.9	(74%)
Fabricated metal products	1.7	0.6	(38%)	1.0	(62%)
Machinery and equipments	3.4	0.3	(7%)	3.2	(93%)
Electrical & electronic machinery	4.1	2.3	(57%)	1.8	(43%)
Transport equipments	2.4	1.0	(41%)	1.4	(59%)
Precision instruments	-0.1	-2.0	–	1.9	–
Other industrial products	-0.4	0.0	–	-0.4	–
Manufacturing	2.8	1.0	(38%)	1.8	(62%)

Notes and *source*: See Table 6.5.

6.2 LONG-TERM TRENDS OF TECHNOLOGICAL PROGRESS AND TECHNICAL EFFICIENCY CHANGE

Unfortunately, large-scale fluctuations in technical efficiency change and technological progress have prevented the long-term trend analysis being undertaken for Hong Kong's manufacturing sector. The cause of the unsatisfactory outcome in Hong Kong is implicitly confirmed by the estimated frontier coefficients as presented in Table 4.3, which shows sizable changes in the estimated constant terms, labour and capital coefficients over time.[72] Thus, in this section the analysis focuses on the manufacturing sectors of Japan, Korea, Singapore and Taiwan only. Note that the comparison of the long-term trends in technological progress and technical efficiency change can also be extended to individual industries.

Figure 6.1 The trends of technical efficiency change and technological progress in Japan's manufacturing sector, 1965–1998

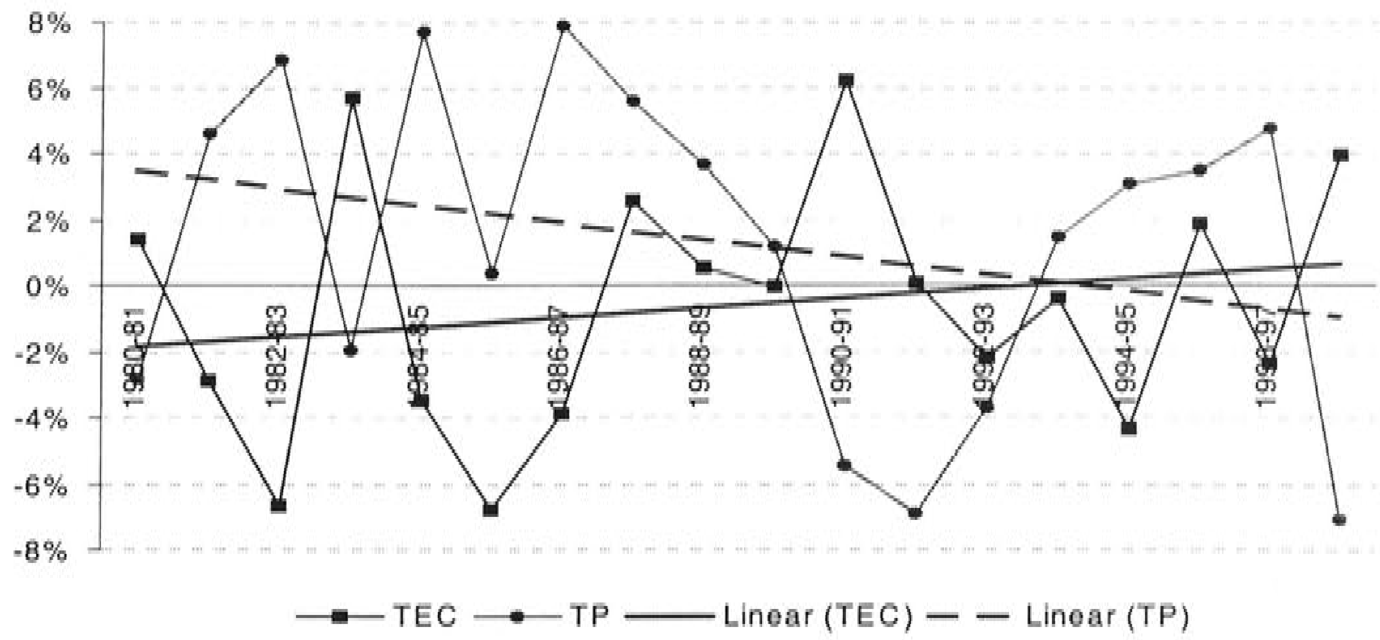


Note: TEC and TP denote technical efficiency change and technological progress, respectively. The linear trends of technical efficiency change and technological progress are obtained using *Windows Excel 2000*.

Source: Author's calculation.

[72] If the frontier production function were estimated with a small upward bias due to data or other unknown problems, i.e., obtaining a larger constant term and labour and capital frontier coefficients, the upward bias of frontier production function would give rise to a smaller technical efficiency improvement but higher technological progress. As a result, there is little change in TFP growth estimates, that is, a large fluctuation in the estimated frontier coefficients has little impact on the calculation of TFP growth estimates.

Figure 6.2 The trends of technical efficiency change and technological progress in Japan's manufacturing sector, 1980–1998



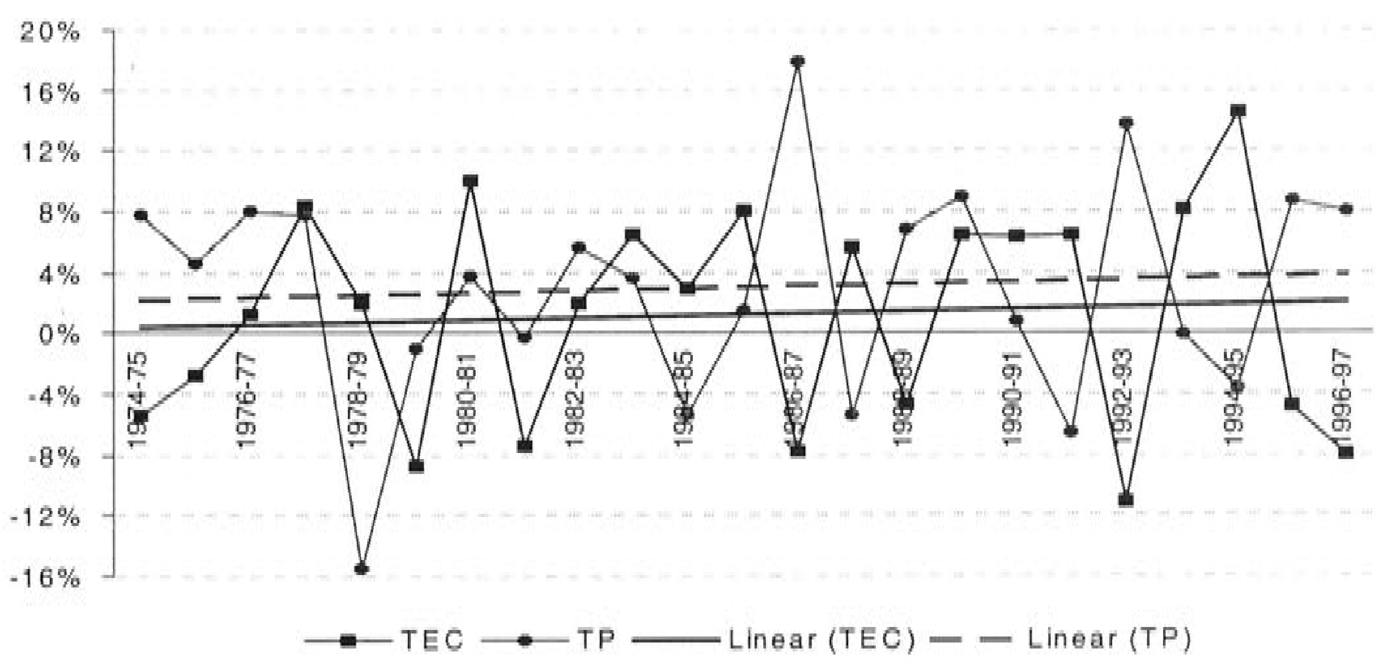
Note and *source*: As Figure 6.1.

Figure 6.1 presents the trends of technical efficiency change and technological progress in Japan's manufacturing sector over the period 1965–98. It clearly shows there has been a systematic transformation in the components of TFP growth over time as indicated by the opposite trends of technical efficiency change and technological progress. The impressive technological progress in Japan's manufacturing sector slowed down over time and even became negative after 1993. Although technical efficiency change was negative at the beginning, it turned out to be positive after 1993. The trends of technical efficiency change and technological progress remain in opposite directions for the Japanese manufacturing sector, even though the sample period is reduced to the 1980–1998 period as indicated in Figure 6.2.

As discussed earlier, TFP growth constitutes both technological progress and technical efficiency improvement. Quite often, higher technical efficiency improvement can compensate for small technological decline and still achieve positive TFP growth. One of the possible scenarios emerging from Figure 6.1 is that technical efficiency improvement has been playing an increasing role in maintaining TFP growth in Japan's manufacturing industries. As production technology has reached a mature stage in Japan, implying that technology upgrade becomes costly, one of the alternatives for maintaining future growth and competitiveness is to engage in improving technical efficiency. On the other hand, ongoing structural change and market reform in Japan may contribute to the exit of inefficient firms and therefore raise the overall technical efficiency level for the entire manufacturing sector.

The intuition behind this is obvious. Since extensive investments in R&D are required in order to upgrade production technology, technical efficiency improvement stemming from a learning-by-doing effect, on-the job training and investment in human capital with far less cost become the easiest (and cheapest) choice to raise the TFP level in Japan. By extension, such an increase in technical efficiency improvement may be viewed as *efficiency-based* or intangible technology in contrast to the physical technology, which provokes technological progress. In addition to the consideration of production cost, the ongoing structural transformation in Japanese manufacturing industries from technological progress towards technical efficiency improvement deserves more empirical study. For instance, this outcome may have a lot to do with government policy because a reduction in subsidy on R&D may discourage firms from being involved in upgrading technology.

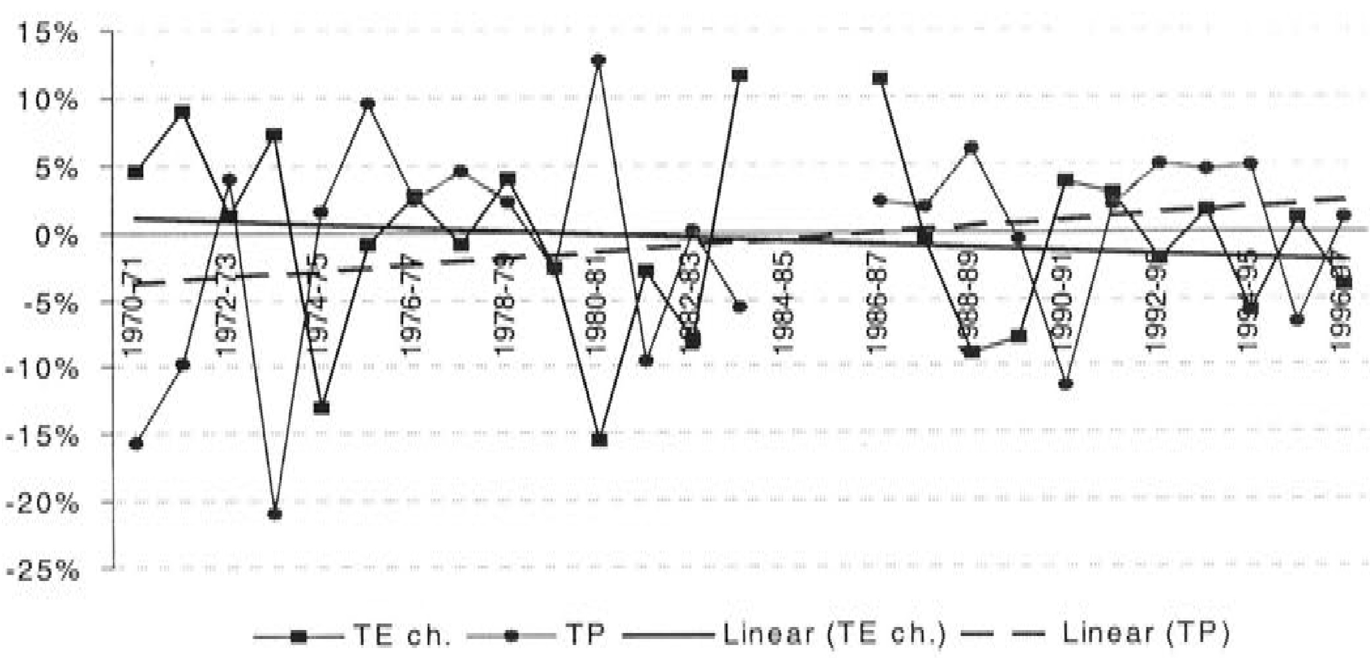
Figure 6.3 The trends of technical efficiency change and technological progress in the Korean manufacturing sector, 1974–1997



Note and *source*: As Figure 6.1.

Figure 6.3 presents the trends of technical efficiency change and technological progress in Korea's manufacturing sector over the period 1974–97. To avoid large-scale fluctuations in technical efficiency change and technological progress in the early 1970s characterised by the oil crisis, the long-term trend analysis for Korean manufacturing sector covers from 1974 to 1997 as shown in Figure 6.3. Note that, if the sample period commences from 1970, the slopes of both trends remain almost unchanged. From a long-term aspect, both trends in technical efficiency improvement and technological progress were upward sloping over the period 1974–97. In other words, technological progress and technical efficiency improvement have been rising since the earlier 1970s. On the one hand, the combination of these two indicates the sustainability of TFP growth in Korea's manufacturing sector. On the other hand, this outcome contradicts the general perception regarding the interaction between technological progress and technical efficiency change. Although technological progress often accompanies deterioration in technical efficiency as suggested by Huggett and Ospina (2001), the finding of this study rejects such a proposition for Korea. Therefore, if Korean manufacturing industries can upgrade their technology (technological progress) and master the new technology quickly (technical efficiency improvement) at the same time, it is possible to maintain both technological progress and technical efficiency improvement.

Figure 6.4 The trends of technical efficiency change and technological progress in Singapore's manufacturing sector, 1970–1984 and 1986–1997



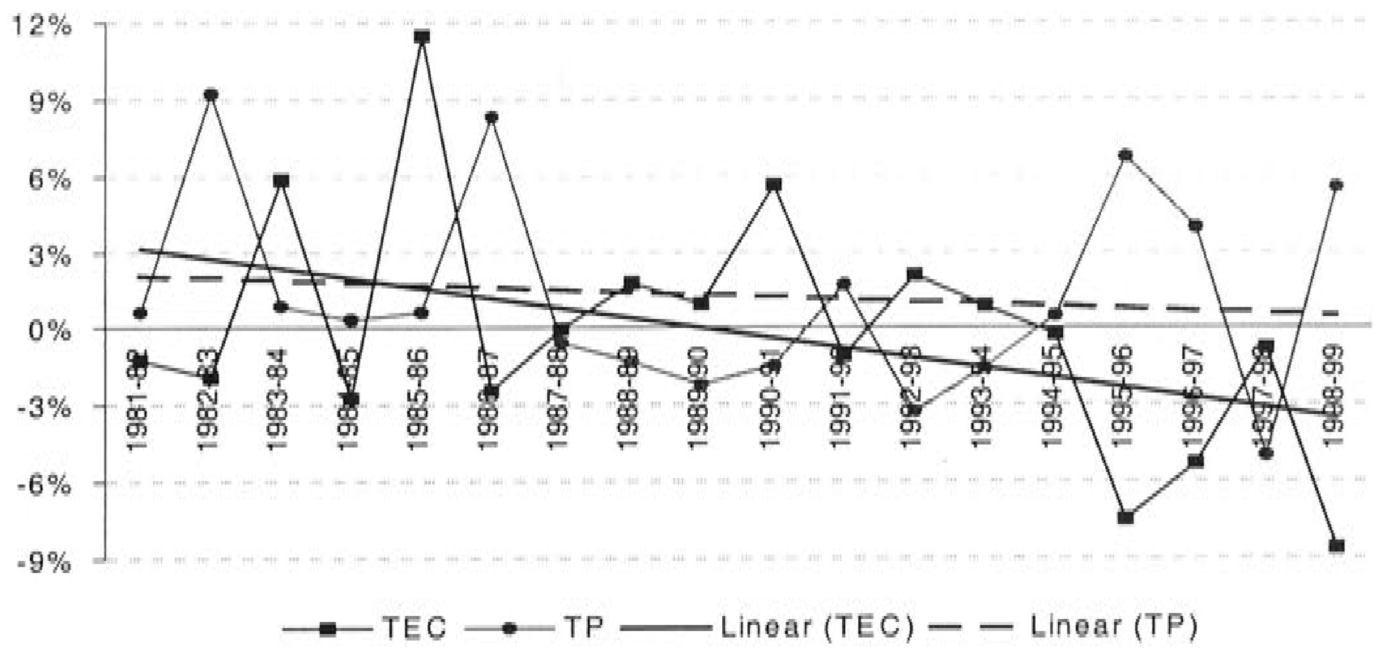
Note and *source*: As in Figure 6.1.

Figure 6.4 presents the trends of technical efficiency change and technological progress in Singapore's manufacturing sector over the period 1970–97. Substantial technological decline with moderate technical efficiency improvement resulted in negative TFP growth in the 1970s. With the disappearance of technical efficiency improvement in the early 1980s, TFP growth on average remained negative over the 1980s. Finally, the moderate technological progress in the 1990s was unable to reverse (offset or compensate) a large decline in the level of technical efficiency and brought about negative TFP growth. Similar to Japan, there has been a systematic transformation in the components of TFP growth for Singapore over time as indicated by the opposite trends of technical efficiency change and technological progress. Nonetheless, the upward-sloping trend of technological progress and the downward-slope trend of technical efficiency are opposite to Japan's scenario.

Given that technical efficiency improvement is often deemed a result of a learning-by-doing effect, on-the-job training and other investments in human capital, Singapore's manufacturing industries have certainly failed to enhance TFP through technical efficiency improvement. By extension, ignorance of technical efficiency enhancement largely accounted for the negative TFP growth for Singapore's manufacturing industries after the mid-1980s. Specifically, the result is consistent with Young (1992, 1995) and Mahadevan and Kalirajan (2000). Young (1992) points out that the continuation of adopting the latest technology represented by technological progress and failure to master existing production technology denoted by technical efficiency deterioration should be responsible for negative TFP growth, because the benefit of advanced technology cannot be entirely realised within a short period of time. Mahadevan and Kalirajan (2000) find evidence that technical efficiency deterioration was the main factor driving down TFP growth in Singapore. Hence, the ongoing structural transformation from technical efficiency improvement in the 1970s towards technological progress in the 1990s deserves more empirical research to uncover the process of such transformation.

Figure 6.5 presents the trends of technical efficiency change and technological progress in Taiwan's manufacturing sector over the period 1981–99. Taiwan's manufacturing sector experienced a downward trend in both technical efficiency change and technological progress. On average, the improvement in technical efficiency fell drastically and turned out to be negative after 1990. Despite technological progress remaining positive, the declining trend implies technological progress would soon become negative. According to the downward-sloping trends in technological progress and technical efficiency improvement, this study questions the sustainability of Taiwan's manufacturing industries due to the sharp slowdown of TFP growth. This drastic TFP slowdown is obviously attributed to technical efficiency deterioration because the extent of technical efficiency deterioration significantly exceeded that of technological decline.

Figure 6.5 The trends of technical efficiency change and technological progress in Taiwan's manufacturing sector, 1981–1999



Note and *source*: As Figure 6.1.

6.3 Sources of TFP Growth: High-Tech versus Low-Tech Industries

Intuitively, high-tech industries are often associated with high TFP growth, yet such empirical comparison has rarely been carried out in the literature. Therefore, this section compares high-tech with low-tech industries based on two hypotheses. The first is whether high-tech industries have higher TFP growth than low-tech ones. The second is whether the sources of TFP growth for high-tech industries stem from technological progress, whereas those for low-tech industries come from technical efficiency improvement.[73] In the literature, there is no precise definition regarding the classification of high-tech and low-tech industries. Therefore, on the basis of capital-labour ratio, low-tech industries defined in this study are textiles, wearing apparel, leather products,

[73] This comparison was motivated by a conversation with Professor Nirvikar Singh.

footwear, wood products, and furniture, also known as labour-intensive or traditional industries.[74]

Although the capital-labour ratio for chemicals, petroleum, and iron and steel industries are generally among the highest, these industries are usually characterised as heavy not high-tech industries. Based on the nature of technology rather than capital-labour ratio, this study classifies the following industries: non-electrical machinery, electric machinery, and professional equipment (or precision instruments) as high-tech. Since the results of the decomposition of TFP growth at the industry level have been exhibited in Tables 6.1 to 6.5, this section will not present them again.

High-tech industries in Hong Kong appear to be more productive than low-tech according to Table 6.1. For instance, the average annual TFP growth rates for the high-tech industries, non-electrical machinery, and electric machinery, were over 4%. However, except for the leather products industry, low-tech industries experienced average annual TFP growth at around 2%; in particular, the footwear industry underwent TFP decline of 1.9%. On the one hand, the hypothesis for Hong Kong's low-tech industries gaining TFP growth from technical efficiency improvement did not hold as a result of five out of six suffering technical efficiency deterioration. For high-tech industries, both technical efficiency improvement and technological progress equally contributed to TFP growth. Therefore, this denies the hypothesis of sources of TFP growth for high-tech industries largely emanating from technological progress.

Two proposed hypotheses prove to be incorrect for Japan's manufacturing industries as both high-tech and low-tech industries enjoyed comparable TFP growth, at roughly 2.7% per annum. As can be seen in Table 6.2, the sources of TFP growth appeared to be similar as well. The proposed hypotheses are also rejected for Korean manufacturing industries for similar reasons to Japan.

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[74] For instance, R&D expenditure ratio is also a good indicator in defining high-tech and low-tech industries; yet, such data are unavailable. Moreover, the ranking of capital-labour ratio for manufacturing industries is based on Japan's data in 1990 and 1995. Despite that the capital-labour ratio for the other manufactured products industry is ranked at the 6th from the bottom, this study considers the textiles (7th from the bottom) industry instead.

In contrast to the above three manufacturing sectors, the two hypotheses for Singapore's high-tech industries reveal mixed results as shown in Table 5.13. One of the high-tech industries, electric machinery, experienced the worst TFP growth but the professional equipment industry gained the highest. Two low-tech industries, including the textiles and leather products, had certain TFP growth; on the contrary, another high-tech industry, non-electrical machinery, obtained little TFP growth. Thereby, the proposition that high-tech industries have higher TFP growth in Singapore is incorrect.

In terms of sources of TFP growth, high-tech industries in Singapore unexpectedly did not enhance TFP growth through technological progress. Nevertheless, with the exception of the furniture industry, low-tech industries gained considerable technical efficiency improvement, especially textiles and leather products. Hence, the proposition of low-tech industries gaining TFP growth through technical efficiency improvement was valid only for the textiles and leather products industries. Ultimately, no matter whether high-tech or low-tech industries, both experienced negative technological progress to a comparable extent.

Analogous to Singapore, mixed results emerge from the comparison between Taiwan's high-tech and low-tech industries. As far as high-tech industries are concerned, the electrical and electronic machinery industry gained average annual TFP growth by 1.7% but TFP growth for the precision instruments industry fell by 1.7% annually. Apart from the wood and furniture industries, the textiles, wearing apparel and leather industries, defined as low-tech, experienced average annual TFP growth of –1.5%, –3.9%, and –5.5%, respectively. Consequently, the first hypothesis is rejected; namely, high-tech industries in Taiwan did not enjoy higher TFP growth in comparison with low-tech ones.

Additionally, the speculation of the sources of TFP growth in high-tech industries emanating mainly from technological progress is generally invalid for Taiwan's manufacturing industries because the electrical and electronic machinery industry experienced TFP growth through technical efficiency improvement and technological progress equally. Instead of gaining TFP growth from technological progress, the precision instruments industry suffered technological decline of 19.7% leading to negative TFP growth. Two low-tech industries, wood and furniture, considerably improved the level of technical efficiency by 39.7% and 84%, respectively, and experienced substantial technological decline. Therefore, the statement of sources of TFP growth for low-tech industries stemming from technical efficiency improvement turns out to be valid only for the wood and furniture industries.

6.4 SENSITIVITY ANALYSIS

Concerns over the gloomy results for Singapore's manufacturing industries raise a number of questions regarding the choice of labour quality adjustment index (1.6% per annum) and capital depreciation rate (0.1768). As Chen (1997) argues that the quality improvement embodied in labour and capital inputs could be over-adjusted in Young (1992, 1995), the impact of various labour quality adjustment indices and capital depreciation rates on the TFP growth estimates will be carefully examined.

Table 6.7 Sensitivity analyses for Singapore's TFP growth estimates, 1970–97

Labour quality indices	Depreciation rates	Output growth	Input growth	TFP growth	TE change	Tech. Progress	Annual TFP growth
1.6%	***0.1768***	**2.526**	**2.748**	**-0.221**	**0.068**	**-0.290**	**-0.008**
	0.20	2.526	2.725	-0.199	0.089	-0.288	-0.007
	0.25	2.526	2.684	-0.158	0.127	-0.284	-0.006
	0.30	2.526	2.652	-0.125	0.156	-0.281	-0.005
1.0%	*0.1768*	2.526	2.662	-0.136	0.154	-0.290	-0.005
	0.20	2.526	2.640	-0.113	0.175	-0.288	-0.004
	0.25	2.526	2.599	-0.072	0.212	-0.284	-0.003
	0.30	2.526	2.566	-0.040	0.241	-0.281	-0.001
0.5%	*0.1768*	2.526	2.591	-0.065	0.225	-0.290	-0.002
	0.20	2.526	2.568	-0.042	0.246	-0.288	-0.002
	0.25	2.526	2.527	-0.001	0.283	-0.284	0.000
	0.30	2.526	2.495	0.032	0.313	-0.281	0.001
0%	*0.1768*	2.526	2.519	0.007	0.297	-0.290	0.000
	0.20	2.526	2.496	0.030	0.318	-0.288	0.001
	0.25	2.526	2.455	0.071	0.355	-0.284	0.003
	0.30	2.526	2.423	0.103	0.385	-0.281	0.004

Notes:
1. Due to rounding, figures above may not add up.
2. The results above are derived based on the estimated frontier coefficients in Table 4.6. If the new labour and capital inputs are used to generate new frontier coefficients, it is believed that new frontier coefficients and the results of using new frontier coefficients will be very similar to Table 4.6 and Table 6.7, respectively.
3. The result of this study is shown in bold.
4. If lower depreciation rate of 0.0925 is used for Singapore, TFP growth over the 1970–97 period becomes –33.4%, i.e., –1.2% per annum.

It is certain that a larger labour quality adjustment index generates higher input growth resulting in lower TFP growth. On the other hand, a larger capital depreciation rate creates higher TFP growth because of less capital input used. In the wake of negative TFP growth for Singapore's manufacturing sector, a series of sensitivity tests are demonstrated using a number of quality adjustment indices and depreciation rates. First, it is suggested that the labour quality adjustment index and capital depreciation rate may influence TFP growth estimates substantially. Hence, the impact of new labour quality adjustment indices of 1%, 0.5% and 0% (no quality improvement) will be examined. Second, instead of using frontier coefficients, the mean coefficients with no random effect derived from the conventional econometric approach are employed to compare with the findings of this study.

Table 6.7 shows the sensitivity analyses for Singapore's TFP growth estimates over the period 1970–97 using three capital depreciation rates (0.20, 0.25, and 0.30) and labour quality improvement indices (1%, 0.5%, and 0%, per annum).[75] It is evident that an increase in capital depreciation rate and decrease in labour quality index generated an impact on the TFP growth estimates for Singapore.[76] Yet, these impacts appear to be insignificant unless the extreme capital depreciation rate (0.3) and labour quality adjustment index (0%) are selected. Even so, it could only raise average annual TFP growth from a negative estimate of –0.8% to a small positive 0.4%. Undoubtedly, the new annual TFP growth estimate of 0.4% is not comparable with those of Hong Kong, Japan and Korea's manufacturing sectors.

On the basis of the mean coefficients in Table 4.6 along with the three capital depreciation rates and labour quality adjustment indices, the result of a sensitivity test for TFP growth estimates as demonstrated in Table 6.8 comes out to be parallel to Table 6.7. Three average annual TFP growth estimates in Table 6.8 uniformly increase by approximately 0.2% and the TFP growth rates of the manufacturing sector over the period

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[75] It should be noted that 'zero' labour quality improvement index might not necessarily imply that there would be no quality improvement in labour input at all. Provided that actual labour input 'hours worked' dropped sharply, the use of number of employees might overstate the actual labour input. The overstatement, say, 0.5%, can be interpreted as labour quality improvement (0.5%) if the labour quality adjustment index is set to be zero. Nevertheless, in this case the labour quality improvement index will be very small, but is unlikely to be 'zero' anyway. Yet, if the true labour input 'hours worked' has not changed over time, the 'zero' labour quality adjustment index will indeed imply no quality improvement in labour input.

[76] In addition, it is observed that when the capital depreciation rate is fixed, say, 0.20, an increase in labour quality adjustment index only alters technical efficiency improvement but not technological progress because the calculation of technological progress is based on the initial capital and labour input.

1970–97 raise by 6–7%. Moreover, it is shown that the mean production frontier technology over the period 1970–97 has little change, represented by the insignificant technological decline of 0.1%, if the labour quality adjustment index and depreciation rate remain as usual (1.6% and 0.1768). But, there was considerable deterioration in technical efficiency, which indicates actual output in 1997 was further away from the average production frontier.

Note that the composition of TFP growth, namely, technical efficiency change and technological progress, in Table 6.7 differs significantly from that of Table 6.8. Intuitively, the former implies that the best practice production frontier in Singapore moved downwards leading to the actual output closer to the production frontier, as a result, technical efficiency improved by 6.8% while technological progress fell by 29%. Nonetheless, the latter shows that there was little change (–0.1%) in mean frontier production technology.

Table 6.8 Sensitivity analyses for Singapore's TFP growth estimates using frontier coefficients versus conventional mean coefficients in Singapore, 1970–97

Labour quality indices	Depreciation rates	Output growth	Input growth	TFP growth	TE change	Tech. Progress	Annual TFP growth
1.6%	***0.1768***	**2.526**	**2.748**	**-0.221**	**0.068**	**-0.290**	**-0.008**
Mean coefficients (conventional econometric approach)							
1.6%	*0.1768*	2.526	2.683	-0.157	-0.156	-0.001	-0.006
	0.20	2.526	2.661	-0.135	-0.137	0.002	-0.005
	0.25	2.526	2.622	-0.096	-0.103	0.008	-0.004
	0.30	2.526	2.591	-0.064	-0.077	0.013	-0.002
1.0%	*0.1768*	2.526	2.598	-0.072	-0.071	-0.001	-0.003
	0.20	2.526	2.576	-0.050	-0.052	0.002	-0.002
	0.25	2.526	2.537	-0.010	-0.018	0.008	0.000
	0.30	2.526	2.505	0.021	0.008	0.013	0.001
0.5%	*0.1768*	2.526	2.526	0.000	0.000	-0.001	0.000
	0.20	2.526	2.504	0.022	0.020	0.002	0.001
	0.25	2.526	2.465	0.061	0.054	0.008	0.002
	0.30	2.526	2.434	0.093	0.080	0.013	0.003
0%	*0.1768*	2.526	2.454	0.072	0.072	-0.001	0.003
	0.20	2.526	2.432	0.094	0.092	0.002	0.003
	0.25	2.526	2.393	0.133	0.125	0.008	0.005
	0.30	2.526	2.362	0.164	0.152	0.013	0.006

Note: As in Table 6.7.

More importantly, it should be stressed that the modelling of industry-specific characteristics in frontier production function is theoretically favourable. Because the conventional stochastic frontier approach does not take industry-specific characteristics into account and simply assumes the application of production technology is identical across industries, which is fundamentally flawed. Finally, the sensitivity analyses show that there is no significant change in the TFP growth estimates using three different labour adjustment indices and capital depreciation rates, which explicitly confirm that the empirical results of this study are pretty robust.

6.5 Comparisons with Earlier TFP Studies

This section compares the findings of this study with earlier TFP studies on manufacturing industries in East Asia. In general, the comparison will be carried out on the basis of manufacturing sector level in most cases, not industry by industry. But, the detailed TFP growth estimates are available in Tables 6.11 to 6.15. Regardless of a wide range of TFP studies on East Asia in the literature, many of them focus on the economy level or manufacturing level.[77] Except for Young (1995) and Timmer and Szirmai (2000), comparative TFP studies among East Asian manufacturing sectors are few. The following comparison with earlier TFP studies for manufacturing industries begins with East Asia, followed by Hong Kong, Japan, Korea, Singapore and Taiwan, respectively.

6.5.1 Comparison for East Asia

Table 6.9 summarises the decomposition results of output growth for the five East Asian manufacturing sectors. Korea enjoyed the highest output and input growth rates of 390.8% and 293.2%, followed by Singapore with 252.6% and 274.8%, respectively. Hong Kong's manufacturing sector experienced negative output and input growth due to manufacturing relocation to mainland China since the mid-1980s. The largest gain in TFP growth occurred in Korea with 97.6%, followed by Japan with 82.8% and Hong Kong with 57.4%, respectively. Taiwan obtained only 4.1% TFP growth in nearly two decades

[77] Many existing TFP studies concentrate on the economy level. For instance, in terms of cross-countries TFP studies, see The World Bank (1993), Young (1994), Collins and Bosworth (1996), and Klenow and Rodriguez-Clare (1997) etc.; for TFP studies on East Asia and Asia Pacific, refer to, among others, Kim and Lau (1994), Young (1995), Sarel (1995), Drysdale and Huang (1997), Gapinski (1997), Singh and Trieu (1999), Chang and Luh (1999), Hsieh (1999, 2002) and so on.

and Singapore's manufacturing sector was the only sector in East Asia to experience negative TFP growth of 22.1%.

Conventionally, TFP growth is often used synonymously with technological progress. As can be seen from Table 6.9, this is misleading, because TFP growth not only reflects technological progress but also captures an improvement in using available resources. In East Asia, technical efficiency improvement played an important role in accounting for TFP growth in Korea, and Taiwan (over the 1981–91 period, see Table 6.6). On the other hand, deterioration in the level of technical efficiency was responsible for the drastic slowdown of TFP growth in Taiwan in the 1990s. In other words, a significant improvement in technical efficiency can raise TFP growth but failure to maintain the technical efficiency level can also lower TFP growth. For instance, if technical efficiency levels in Japan had been maintained, TFP growth would have been higher. On examining the contribution to TFP growth, technological progress has been critical in the manufacturing sectors of Hong Kong, Japan, Korea and Taiwan, respectively. In the cases of Japan and Taiwan, TFP growth can completely be accounted for by technological progress. Yet, negative technological progress was the main cause for negative TFP growth in Singapore.

Table 6.9 Decomposition of output growth for five East Asian manufacturing sectors

Country	Period	Output growth	Input growth	TFP growth	TE change	Tech progress
Hong Kong	1976–97	-0.068	-0.642	0.574	0.056	0.519
Japan	1965–98	1.589	0.761	0.828	-0.322	1.150
Korea	1970–97	3.908	2.932	0.976	0.289	0.687
Singapore	1970–97	2.526	2.748	-0.221	0.068	-0.290
Taiwan	1981–99	1.169	1.128	0.041	-0.038	0.080

Source: From earlier tables presented in Chapters 5 and 6, respectively.

Despite different methodologies, the findings of this study have coincided with some recent empirical studies on East Asian manufacturing sectors. Table 6.10 presents a brief comparison between this study, Young (1995) and Timmer and Szirmai (2000). Regrettably, Hong Kong and Japan are not covered in Young (1995) or Timmer and Szirmai (2000). Yet, this study points out that Hong Kong and Japan's manufacturing sectors enjoyed 2.7% and 2.5% annual TFP growth, respectively, over the 1976–97 and

1965–98 periods. For Korea, this study finds average annual TFP growth of 3.6% over the period 1970–97, which is between the 4.5% of Timmer and Szirmai (2000) and the 3.0% found by Young (1995). As for Singapore's manufacturing sector, the finding of an average annual TFP growth rate of –0.8% during the 1970–97 period is in fact in line with the –1.0% of Young (1995).

Table 6.10 TFP studies for manufacturing sectors in East Asia

Country	Period	This study	Timmer and Szirmai (2000)	Young (1995)
		TFP growth p.a.	TFP growth p.a.	TFP growth p.a.
Hong Kong	1976–97	0.027	—	—
Japan	1965–98	0.025	—	—
Korea	1970–97	0.036	0.045 (1963–93)	0.030 (1966–90)
Singapore	1970–97	-0.008	—	-0.010 (1970–90)
	1975–97	0.004	—	-0.011 (1980–90)
Taiwan	1981–99	0.002	0.020 (1963–93)	0.014 (1966–90)
	1981–91	0.028	—	0.027 (1980–90)

Notes: 1. The figures, e.g., 1963–93, in parentheses denote the sample period.
2. The TFP growth of manufacturing sector in Timmer and Szirmai (2000) is at aggregate level not output-weighted TFP growth and the result of Korean manufacturing sector excludes firms with less than five people. For Taiwan, their study includes all firms.

Sources: Timmer and Szirmai (2000, p. 380, Table 2); Young (1995, p. 660, Table VII and p. 661, Table III).

For Taiwan, the sample period of this study differs from those of Young (1995) and Timmer and Szirmai (2000).[78] As shown in Table 6.10, this study suggests Taiwan's manufacturing sector obtained 2.8% and 0.2% annual TFP growth over the periods 1981–91 and 1981–99, respectively. Due to the fact that the slowdown of TFP growth in Taiwan's manufacturing sector occurred after 1991 as indicated in Table 5.6, the estimated annual TFP growth rates of 2.0% and 1.4% over the periods 1963–93 and 1966–90 by Timmer and Szirmai (2000) and Young (1995), respectively, appear to be higher than this study's finding of 0.2% over the period 1981–99. However, if the period of TFP slowdown, i.e., 1992–99, is excluded, the finding of 2.8% annual TFP growth in this study for Taiwan's manufacturing sector during the period 1981–91 was consistent

[78] The average annual TFP growth estimates of 4.5% for Korea and 2% for Taiwan's manufacturing sector are calculated at the aggregate level in Timmer and Szirmai (2000). The output-weighted sectoral TFP growth rates are estimated to be higher for Korea at 4.9% per annum, and lower for Taiwan at 1.7%, respectively.

with the 2.7% over the 1980–90 period reported by Young (1995). Finally, it should be noted that this study derives the (weighted) TFP growth estimates for each manufacturing sector in East Asia while Young (1995) estimates TFP growth by employing aggregate data at the manufacturing level. Quite often, differences may arise because of aggregation problems. A detailed comparison for each economy is presented next.

6.5.2 Comparison for Hong Kong

Despite having relatively less TFP empirical work, Kwong *et al.* (2000) offer a comprehensive study for Hong Kong's manufacturing industries. Table 6.11 provides a detailed comparison between Kwong *et al.* (2000) and this study. In spite of 15 out of 29 industries recording TFP progress, they find evidence that the overall manufacturing sector experienced a surprising technology decline of 13.8% during the 1984–93 period, due to the rapid relocation of manufacturing production to mainland China. In contrast, this study suggests a somewhat optimistic result of 23.3% TFP growth over the same period. Apart from the tobacco and petroleum and coal industries, to some extent, the TFP growth estimates of several industries are comparable between these two with respect to signs and magnitudes, such as the beverages, wearing apparel and rubber industries. Nevertheless, there are large distinctions in the industries, such as the non-metallic minerals, basic metals, non-electrical machinery, and transport equipment.

Except for 1989–90, the annual TFP growth rate for the entire manufacturing sector suggested by Kwong *et al.* (2000, p. 186, Table 2) appeared to be stagnant roughly between –3% to 1%, while as indicated earlier in Figure 5.1 this study shows that annual TFP growth fluctuated significantly. Overall, there are substantial differences between these two studies during the 1984–87 period due to the different methodologies and measurements of manufacturing output. Kwong *et al.* (2000) use 'gross output' instead of value added and implicitly claim that the use of value added would overstate the true contribution of factor inputs in Hong Kong.[79] Other TFP studies on Hong Kong's manufacturing industries, such as Imai (2001) and Tuan and Ng (1995), are incomplete and have already been described in Chapter 2. Their results are not reiterated here.

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[79] Kwong *et al.* (2000, p. 173) explain the reason for using gross output instead of value added in footnote 4.

Table 6.11 TFP studies for manufacturing industries in Hong Kong

Industries	Kwong *et al.* (2000)	This study	This study
	1984–93	1984–93	1976–97
	TFP growth	TFP growth	TFP growth
Food manufacturing	0.50641	0.203	0.611
Beverages	0.57093	0.436	0.192
Tobacco manufacturing	-0.38376	—	—
Wearing apparel	0.10653	0.122	0.488
Textiles	0.42498	0.090	0.389
Leather products	0.09220	0.370	0.861
Footwear (non-rubber)	-0.11068	-0.724	-0.218
Wood and cork products	-0.05626	0.103	0.466
Furniture (non-metal)	-0.01700	0.118	0.363
Paper products	0.16938	0.389	0.502
Printing and publishing	0.69813	0.306	0.560
Chemicals	-0.64548	0.283	0.564
Petroleum and coal#	-0.80850	—	—
Rubber	0.35674	0.355	0.690
Plastics	-0.25692	0.183	0.632
Non-metallic minerals	-0.37367	0.684	0.848
Basic metals	-0.18314	0.570	0.338
Fabricated metals	0.18189	0.390	0.668
Non-electrical machinery*	-0.40745	0.227	0.830
Office machinery$	-0.01882	—	
Consumer electronics*	0.17079	0.363	0.974
Radio, TV, comm. Equip$	0.01475	—	—
Electrical and electronic parts*	0.18604	—	—
Electronic parts and components$	0.26626	—	—
Electrical app. and electronic toys$	-0.04677	—	—
Scientific equipment	0.10117	0.313	0.515
Transport equipment	-0.52739	0.419	0.590
Other machinery$	0.30221	0.130	0.515
Others	-0.54587	—	—
Manufacturing	-0.13827	0.233	0.574

Note: (#) The sample period of petroleum and coal industry is from 1988–93, (*) from 1984–89 and ($) from 1990–93.

Source: Kwong *et al.* (2000, p. 188, Table 3).

6.5.3 Comparison for Japan

Table 6.12 reports a comparison with earlier TFP studies for Japan's manufacturing industries. With respect to individual industries, this study suggests the average annual TFP growth rates for the industrial chemicals and other chemicals industries over the period 1965–98 were 2.8% and 2.9%, respectively, which are higher than an earlier study of Kumbhakar *et al.* (2000) indicating from 1.553% to 1.716% for the chemical industry during the period 1968–87. For the auto industry, the finding of this study is incomparable with that of Fuss and Waverman (1990) because there is no auto industry classification at the 3-digit level in the UNIDO database. Note that the estimates for manufacturing industries in Griliches and Mairesse (1990) are also not comparable with other TFP studies due to unweighted firm averages and the inclusion of multinational firms.

With the exception of three industries with negative TFP growth in Jorgenson *et al.* (1987), all industries enjoyed various extents of TFP growth according to these studies. Significant TFP growth was seen in the electric machinery (8.4%) and professional equipment (8.1%) industries in Griliches and Mairesse (1990). The professional industry was reported to have had relatively higher TFP growth and, except for Nakajima *et al.* (1998), most studies describe the petroleum refineries industry as experiencing relatively lower TFP growth.

As for the entire manufacturing sector, TFP growth ranges from 0.83% in Jorgenson *et al.* (1987) to 3.73% in Nakajima *et al.* (1998). Unlike other studies, this study extends the sample period to the 1990s, which was characterised as a period of economic recession and slowdown in TFP growth. Thus, it is understandable that the average annual TFP growth estimates reported in this study are reasonably lower than those of Griliches and Mairesse (1990) and Nakajima *et al.* (1998). On the other hand, the TFP growth estimate of this study for the manufacturing sector is substantially higher than that of Norsworthy and Malmquist (1983), Jorgenson *et al.* (1987), and Morrison (1990a) but is parallel to Prasad (1997) and Sato (2002), who also extend the sample period to the 1990s.

Table 6.12 TFP studies for manufacturing industries in Japan

Industries	This study	Jorgenson *et al.* (1987)	Griliches and Mairesse (1990)	Denny *et al.* (1992)	Nakajima *et al.* (1998)
	1965–98 TFPG p.a.	1960–79 TFPG p.a.	1973–80 TFPG p.a.	1954–88 TFPG p.a.	1964–88 TFPG p.a.
311 Food products	0.021	-0.0123	0.007	0.0023	0.02167
313 Beverages	0.041	as food	as food	as food	as food
314 Tobacco	—		—	—	—
321 Textiles	0.029	0.0029	—	0.0240	0.02281
322 Wearing apparel	0.022	0.0101	—	—	0.05027
323 Leather products	0.025	0.0067	—	—	0.03996
324 Footwear	0.029	—	—	—	—
331 Wood products	0.027	0.0188	—	—	0.02313
332 Furniture	0.028	0.0101	—	—	0.04135
341 Paper and products	0.021	0.0088	—	0.0126	0.02961
342 Printing and publishing	0.027	-0.0008	—	—	—
351 Industrial chemicals	0.028	0.0245	0.006	0.0199	0.02956
352 Other chemicals	0.029	—	—	—	—
353 Petroleum refineries	0.006	-0.0316	—	0.0142	0.05489
354 Miscellaneous petroleum	0.024	—	—	—	—
355 Rubber products	0.024	0.0059	as chemical	—	0.04627
356 Plastic products	0.028	—	—	—	as rubber
361 Pottery, china, earthenware	0.021	0.0120	—	0.0135	0.03196
362 Glass and products	0.019	as pottery	—	as pottery	as pottery
369 Other non-metallic mineral	0.030	as pottery	—	as pottery	as pottery
371 Iron and steel	0.028	0.0090	0.016	0.0114	0.04480
372 Non-ferrous metals	0.018	0.0012	as iron	as iron	0.03759
381 Fabricated metal products	0.026	0.0191	—	0.0205	0.03218
382 Non-electrical machinery	0.029	0.0129	0.046	0.0185	0.02707
383 Electric machinery	0.019	0.0328	0.084	0.0323	0.05186
384 Transport equipment	0.020	0.0307	0.044	0.0205	0.04332
385 Professional equipment	0.032	0.0263	0.081	0.0328	0.04324
390 Other manufactured	0.025	0.0289	0.017	0.0187	—
300 Manufacturing	0.025	0.0083	0.036	0.0186	0.03731

Notes: 1. Thirteen industries covered in Denny *et al.* (1992) are not parallel to other studies due to industry aggregation; particularly, miscellaneous manufacturing industry contains eight industries. The detail of aggregation is available in Denny *et al.* (1992, p. 589).
2. The average annual TFP growth rates for the manufacturing sector in Nakajima *et al.* (1998), Denny *et al.* (1992), Jorgenson *et al.* (1987) reported here are simple averages of individual industries. Since these results are not weighted by industry share in manufacturing GDP, they must be interpreted with caution.

Sources: The estimates in Nakajima *et al.* (1998) is from p.325, Table 2, in Denny *et al.* (1992) from p. 590, Table 1, in Jorgenson *et al.* (1987) from pp. 12–15, Table II, and in Griliches and Mairesse (1990) from p. 325, Table 11.5.

6.5.4 Comparison for Korea

Table 6.13 presents a comparison of recent TFP studies on Korea's manufacturing industries. Apart from the study by Kim (2000) and the glass industry in Dollar and Sokoloff (1990), all studies indicate that TFP growth was positive across industries over the different periods of time. It should be mentioned that the classification of industries differs in several studies. For instance, paper and printing are considered as one industry in Pilat (1995), Okuda (1997) and Kim and Han (2001) but are considered separately in this study. Moreover, compared with the industrial classification of the UNIDO database, which has 28 industries at the 3-digit level, Kim (2000) covers 36 manufacturing industries. As a result, some of his TFP growth estimates are simply averaged to be comparable with others. More specific details are available in the notes of Table 6.13.

Irrespective of different time periods and methodologies, the annual TFP growth rates for individual industries fluctuate drastically from study to study, say, from –1.7% in Kim (2000) to over 7% in Dollar and Sokoloff (1990) for the food industry. Another example is the leather industry ranging from 1.1% in Kim (2000) to 12.7% in Dollar and Sokoloff (1990). Although these results remain volatile at the industry level, except for Kim (2000) there is some consensus regarding the extent of TFP growth for a number of industries. For instance, the average annual TFP growth rates for wearing apparel was over 3% and for the non-electrical machinery industry over 4%.

With respect to the entire manufacturing sector, Kim (2000) claims the Korean manufacturing sector experienced a small annual TFP growth rate of 0.5% between 1966 and 1988, whereas the average annual TFP growth estimates range from 3.2% in Okuda (1997) to 7.3% in Kim and Han (2001). This comparison for the Korean manufacturing sector is certainly not exhaustive. The TFP growth estimates at the manufacturing level are also available in Kwon (1986), Kang and Kwon (1993), Park and Kwon (1995), Young (1995), Hwang (1998), Kwack (2000), Timmer and Szirmai (2000), Yuhn and Kwon (2000) and so on; see Chapter 2 for details.[80]

[80] It is worth pointing out that Park and Kwon (1995) and Hwang (1998) even employ two methods to obtain two different results.

Table 6.13 TFP studies for manufacturing industries in Korea

Industries	This study	Nishimizu & Robinson (1984)	Dollar & Sokoloff (1990)	Pilat (1995)	Okuda (1997)	Kim (2000)	Kim and Han (2001)
	1970–97 TFP p.a.	1960–77 TFP p.a.	1963–79 TFP p.a.	1967–87 TFP p.a.	1970–93 TFP p.a.	1966–88 TFP p.a.	1980–94 TFP p.a.
311 Food products	0.027	0.0526	0.072	0.007	0.033	-0.017	0.071
313 Beverages	—	—	0.065	—	—	0.020	—
314 Tobacco	—	—	0.080	—	—	0.064	—
321 Textiles	0.043	0.0451	0.045	0.054	0.030	0.007[a]	0.077
322 Wearing apparel	0.043	0.0162	0.093	0.015	—	0.007	—
323 Leather products	0.041	0.0280	0.127	0.031	—	0.011	—
324 Footwear	0.028	—	—	—	—	as leather	—
331 Wood products	0.049	0.0562	0.030	0.070	—	0.004	—
332 Furniture	0.030	0.0488	0.092	—	—	as wood	—
341 Paper and products	0.040	0.0452	0.009	0.068	0.044	-0.007	0.054
342 Printing and publishing	0.042	—	0.060	—	—	-0.023	—
351 Industrial chemicals	0.033	0.0449	0.012	0.021	0.015	0.026	0.061
352 Other chemicals	0.027	—	0.126	—	—	-0.010	—
353 Petroleum refineries	—	0.0068	0.108	—	0.00	-0.004	—
354 Miscellaneous petroleum	0.024	—	—	—	—	0.002	—
355 Rubber products	0.039	0.0588	0.083	0.075	—	0.005	—
356 Plastic products	0.014	—	0.102	as rubber	—	0.015	—
361 Pottery, china, earthenware	0.083	0.0433	0.036	0.026	0.016	0.012	0.051
362 Glass and products	0.025	—	-0.041	—	—	-0.004	—
369 Other non-metallic mineral	0.057	—	0.001	—	—	0.000	—
371 Iron and steel	0.031	0.0187	0.025	0.023	0.084	0.003	0.058
372 Non-ferrous metals	0.061	—	0.081	—	—	-0.006	—
381 Fabricated metal products	0.037	0.0601	0.104	—	—	0.010	0.094
382 Non-electrical machinery	0.042	0.0573	0.062	0.097	0.076	0.021[b]	—
383 Electric machinery	0.035	0.0725	0.104	0.104	0.038	-0.011[c]	—
384 Transport equipment	0.028	0.0510	0.087	—	0.060	-0.004[d]	—
385 Professional equipment	0.056	—	0.080	—	—	0.046	—
390 Other manufactured	0.027	—	—	0.082	0.007	0.015	—
300 Manufacturing	0.036	0.0371	0.061	0.043	0.032	0.005	0.073

Notes: 1. The following figures in parentheses denote average annual TFP growth estimates. (a) This result is derived from a simple average of three industries, fibre yarn and textile fabrics (0.01), fabric products (–0.02) and other fabricated textiles (0.03). (b) The estimate consists of three industries, power generating machinery (0.030), metalworking and industrial machinery (0.019), and office and other general machinery (0.015). (c) This estimate includes four industries: electrical industrial apparatus (–0.008), electronic and commercial equipment (0.026), household electrical appliance (–0.045), and other electrical equipment (–0.015). (d) The estimate constitutes shipbuilding and repairing (–0.012), railroad vehicles (0.007), motor vehicles (0.002), aircraft and transport equipment (–0.013).

2. The empirical result of Kim and Han (2001) is based on the manufacturing firms listed in the Korean Stock Exchange and subsequently grouped into seven industries at the 2-digit level. The seven industries include food, textiles, paper, chemical, non-metal, basic metal and fabrication.

3. Okuda (1997) regroups the 28 Korean manufacturing industries into 11 industries in his paper. For more details, see Okuda (1997, p. 380).

4. The industry entitled 'manufactures, n.e.c.' in Dollar and Sokoloff (1990) cannot be matched with this study; hence, it is assumed to be the professional equipment industry.

5. Nishimizu and Robinson (1984) examine 16 Korean manufacturing industries.

Sources: The result in Kim (2000) is from p. 77, Table 7, in Nishimizu and Robinson (1984) from p. 201, Table A.1, in Pilat (1995) from p. 141, Table 8, in Kim and Han (2001) from Table 4, Okuda (1997) from p. 364, Table I, and in Dollar and Sokoloff (1990) from p. 319, Table 4.

6.5.5 Comparison for Singapore

Table 6.14 shows a comparison of TFP studies for Singapore's manufacturing industries. The estimated annual TFP growth rates for the manufacturing sector range from –0.8% in this study to 2.8% in Leung (1997). Given the double-digit output growth, Tsao (1985) argues that manufacturing industries in Singapore benefited little from TFP growth in the 1970s because TFP only grew at 0.08% annually. Wang and Gan (1994) and Leung (1997) both claim Singapore's manufacturing sector made certain TFP progress in the 1980s irrespective of the economic recession in 1985. Nonetheless, using a longer data set, this study suggests Singapore's manufacturing sector experienced an average annual TFP growth rate of –0.8% between 1970 and 1997, which is consistent with Young (1995), where he estimates –1% TFP growth over the 1970–90 period.

Analogous to Korean manufacturing industries, the TFP growth estimates for the industry level vary widely. On the basis of Tsao (1985), Wang and Gan (1994) and this study, the electrical machinery industry, regarded as a high-tech one, experienced negative TFP growth. By contrast, it gained substantial TFP progress according to Leung (1997) and Bloch and Tang (1999). Such inconsistent TFP growth estimates also appear in other industries, e.g., the leather and industrial chemicals, as indicated by Table 6.14.

The studies by Rao and Lee (1995) and Mahadevan and Kalirajan (2000) coincidently exclude the 1984–87 period of economic recession. After estimating TFP growth for two separate periods, their results contradict each other. Rao and Lee (1995) indicate that Singapore's manufacturing sector experienced –0.4% TFP growth over 1976–84 the period but Mahadevan and Kalirajan (2000) arrived an average annual TFP growth of 0.92% for the same period. The results remain inconsistent over the later period 1987–94, that is, 3.2% in Rao and Lee (1995) versus –0.52% in Mahadevan and Kalirajan (2000).

In line with Tsao (1985) and Young (1995), the bottom line emerging from this study indicates that TFP growth in Singapore over the past two and half decades was negligible but the extent of TFP decline improved gradually over recent years. While Tsao (1985), Young (1995), Huff (1999) and Ermisch and Huff (1999) have offered a number of explanations for the causes of negative TFP growth, case studies on individual industries, e.g. electric machinery (electronics) industry, will contribute more insight to this controversial debate.

Table 6.14 TFP studies for manufacturing industries in Singapore

Industries	This study	This study	Tsao (1985)	Wong and Gan (1994)	Leung (1997)	Bloch and Tang (1999)
	1970–97	1975–97	1970–79	1981–90	1983–93	1975–94
	TFPG p.a.	TFPG p.a.	TFPG p.a.	TFPG p.a.	TFPG p.a.	Tech ch. p.a.
311 Food products	0.001	0.005	0.0062	0.0151	0.030	—
313 Beverages	-0.011	0.002	0.0173	-0.0214	-0.010	—
314 Tobacco	—	—	0.0322	0.1122	-0.013	0.0485
321 Textiles	0.019	0.038	-0.0323	-0.0521	0.048	—
322 Wearing apparel	-0.004	0.011	-0.0211	0.0205	0.016	-0.0094
323 Leather products	0.015	0.024	-0.0306	-0.0467	0.030	0.0027
324 Footwear	0.008	0.010	-0.0991	0.0049	0.058	0.0561
331 Wood products	-0.003	0.033	-0.0657	-0.0459	0.053	0.0029
332 Furniture	-0.017	0.007	-0.0244	-0.0201	0.033	—
341 Paper and products	0.009	0.018	0.0218	-0.0397	0.034	-0.0478
342 Printing and publishing	0.009	0.011	-0.0136	0.0035	-0.012	0.0007
351 Industrial chemicals	-0.004	0.007	-0.0024	-0.0299	0.024	0.0403
352 Other chemicals	—	—	0.0480	0.0248	0.073[d]	-0.0561
353 Petroleum refineries	—	—	—	—	0.026	0.0073
354 Miscellaneous petroleum	—	—	0.0149	0.0264	—	as petrol.
355 Rubber products	-0.018	0.004	-0.0157	-0.0465	0.030	-0.0082
356 Plastic products	-0.006	0.013	-0.0316	-0.0607	0.045	-0.0746
361 Pottery, china, earthenware	0.010	0.004	-0.0303	-0.1967[b]	-0.030	—
362 Glass and products	as pottery	as pottery	as pottery	as pottery	as pottery	—
369 Other non-metallic mineral	0.010	-0.002	-0.0117[a]	-0.0471[c]	0.041[e]	—
371 Iron and steel	-0.024	-0.007	0.0341	-0.0077	0.006	0.0117
372 Non-ferrous metals	-0.019	0.000	-0.1387	0.0281	0.008	—
381 Fabricated metal products	-0.019	-0.012	-0.0359	-0.0335	0.038	-0.0346
382 Non-electrical machinery	0.001	0.006	-0.0328	-0.0232	0.043	0.0022
383 Electric machinery	-0.032	-0.013	-0.0004	-0.0054	0.038[f]	0.0654
384 Transport equipment	-0.008	0.013	0.0127	0.0556	0.037	0.0000
385 Professional equipment	0.035	0.044	—	0.0039	0.023	-0.0246
390 Other manufactured products	0.016	0.012	—	—	0.008	-0.0814
300 Manufacturing	-0.008	0.004	0.008	0.016	0.028	—

Notes: 1. (a) This is a simple average of the annual TFP growth rates for the concrete, structural clay, cement products were -0.0536, -0.0563, -0.0378, respectively. (b) This figure is from Wong (1993) because it is not reported in Wong and Gan (1994). However, these TFP growth estimates are derived from the same author. (c) The average annual TFP growth rates for the concrete, structural clay, cement products were 0.1072, -0.0554, 0.0468, respectively. (d) This estimate is for the pharmaceutical industry. (e) The average annual TFP growth rates for the bricks/ tiles, cement, and concrete product industries were 0.049, 0.099, and 0.022, respectively. (f) This includes the electronics industry, which had an average annual TFP growth rate of 0.008.

2. In addition, Bloch and Tang (1999) use the conventional growth accounting to estimate TFP growth for the 19 industries, which is available in Table 1, p. 700.

Sources: The result of Leung (1997) is from p. 526, Table 1, Bloch and Tang (1999) from p. 700, Table 1, Tsao (1985) from p. 29, Table 1, Wong and Gan (1994) from p. 182, Table 2, and Bloch and Tang (1999) from p. 700, Table 1.

6.5.6 Comparison for Taiwan

Table 6.15 reports a comparison with earlier TFP studies for Taiwan's manufacturing industries.[81] Despite the similarities and differences revealed in Table 6.15, these results must be interpreted with care because the estimated TFP growth rates are derived from different sample periods, methodologies and even industrial classification and aggregation. As to industrial classification, the classification of industry may vary from study to study. For example, Okuda (1994) aggregates 18 industries into 11 and the industrial classification used by Chen and Tang (1990) is on the basis of the old version. In addition, using firm-level data, Aw *et al.* (2001) group Taiwan's firms into 11 industries at the 2-digit level.

This study finds an average annual TFP growth rate of 2.8% for Taiwan's manufacturing sector between 1981 and 1991, which is parallel to many earlier studies, such as Okuda (1994), Young (1995), Liang and Jorgenson (1999), and Färe *et al.* (2001). For the period 1981–99, this study shows the average annual TFP growth rate fell to only 0.2% implying the dramatic slowdown of TFP growth over the last decade. In contrast, Hu and Chan (1999) and the report by DGBAS (2000) optimistically point out average annual 3.1% and 1.9% TFP growth rates for the manufacturing sector over the periods 1979–96 and 1978–98, respectively. With regard to the extent of TFP growth for individual industries, there is some consensus. For instance, the precision industry experienced negative TFP growth, and apart from Liang (1995), all studies report that the electronic industry achieved reasonable TFP progress, ranging from 1.7% in this study to 5% in Okuda (1994).

In terms of sources of TFP growth, Färe *et al.* (2001) point out that technological progress (2.56%) accounted for most of the TFP growth (2.89%) in Taiwan's manufacturing sector during the 1978–92 period. Yet, this study demonstrates that the contribution of technical efficiency improvement to TFP growth outweighed that of technological progress over the period 1981–91 as shown in Table 6.6.

[81] It should be noted that some TFP studies for Taiwan's manufacturing sector are not included in Table 6.15. Chuang (1996) and Timmer and Szirmai (2000) provide TFP growth estimates only for the manufacturing sector. For details, see Chapter 2, TFP studies review for Taiwan.

Overall, for a number of reasons some differences arise between this study and earlier studies. First, in contrast to growth accounting assumption of firms with full efficiency, the model used in this study recognises the existence of firm's inefficiency. Second, different approaches towards the construction of production frontier may shed light on the discrepancies. The varying coefficients frontier approach used in this study considers the nature of industries, namely, different applications of production technology, and builds the best practice production frontier for individual industries. Conversely, the conventional stochastic frontier approach does not allow for industry-specific characteristics and results in constant capital and labour shares across industries, ignoring firm's heterogeneous behaviour in applying the best available technology. Finally, the adjustment of quality improvement embodied in capital and labour inputs has been cautiously carried out in this study using the estimates of Young (1995). Whereas, the earlier studies do not take into account quality improvement and therefore certainly underestimate input growth and subsequently overstate TFP growth.

Table 6.15 TFP studies for manufacturing industries in Taiwan (continued)

Industries	This study	This study	Chen and Tang (1990)	Liang (1995)	Liang and Jorgenson (1999)
	1981–99 TFPG p.a.	1981–1991 TFPG p.a.	1968–82 TFPG p.a.	1973–82 TFPG p.a.	1982–93 TFPG p.a.
Food processing	—	—	-0.0015	0.0432	0.0309
Beverages and tobacco	—	—	0.0088	0.0005	0.0476
Food, beverages and tobacco	-0.004	0.015	—	—	—
Textile mill products	-0.015	0.021	0.0346	0.0456	0.030
Wearing apparel, accessories*	-0.039	0.016	0.0202	-0.0288	-0.0041
Leather, fur and products	-0.055	-0.015	0.0413	0.0491	-0.0022
Wood and bamboo products	0.015	0.048	-0.0076	-0.1744	0.0057
Furniture and fixtures	0.027	0.031	—	as wood	as wood
Pulp, paper and paper products	-0.043	-0.031	-0.0001	-0.1202	0.0085
Printing processings	-0.040	-0.047	—	as paper	as paper
Chemical material	0.039	0.066	-0.0067	0.0015	0.1075
Chemical products	0.036	0.044	—	as chemical	0.0332
Petroleum and coal	—	—	-0.0063	-0.1447	0.0068
Rubber products	-0.023	0.012	0.0207	-0.0239	0.0201
Plastic products	0.017	0.060	—	as chemical	-0.017
Non-metallic mineral products	0.020	0.045	0.0099	-0.0137	0.0451
Basic metal industries	0.019	0.053	0.0004	0.0002	0.0858
Fabricated metal products	-0.013	0.017	0.0142	-0.0396	0.0145
Machinery and equipments	0.004	0.034	0.0363	-0.0001	0.0475
Electrical and electronic mach.	0.017	0.041	0.0212	-0.0168	0.0444
Transport equipments	-0.022	0.024	0.0226	-0.0176	0.0271
Precision instruments	-0.017	-0.001	—	—	—
Other industrial products	-0.016	-0.004	—	0.0275	0.0133
Manufacturing	0.002	0.028	—	0.0012	0.0272

TFP studies for manufacturing industries in Taiwan

Industries	Okuda (1994)	Hu and Chan (1999)	DGBAS (2000)	Färe *et al.* (2001)	Aw *et al.* (2001)
	1978–91 TFPG p.a.	1979–96 TFPG p.a.	1978–98 TFPG p.a.	1978–92 TFPG p.a.	1981–91 TFPG p.a.
Food processing	—	—	0.009	0.0484	—
Tobacco	—	—	0.017	—	—
Food, beverages and tobacco	0.023	0.009	—	—	—
Textile mill products	0.039	0.022	0.020	0.0574	0.0317
Wearing apparel, accessories*	0.021	0.019	-0.009	0.0113	0.0078
Leather, fur and products	0.028	0.015	-0.004	0.0007	—
Wood and bamboo products	0.021	0.017	0.017	0.0012	—
Furniture and fixtures	—	as wood	as wood	as wood	—
Pulp, paper and paper products	0.005	-0.012	-0.015	0.0172	—
Printing processings	—	as paper	as paper	as paper	—
Chemical material	0.010	0.040	0.040	0.0849	0.0366
Chemical products	—	as chemical	as chemical	as chemical	—
Petroleum and coal	—	0.029	-0.023	—	—
Rubber products	—	as chemical	as chemical	0.0313	—
Plastic products	—	as chemical	0.014	as chemical	0.0238
Non-metallic mineral products	0.010	0.020	0.020	0.0380	—
Basic metal industries	0.012	0.013	0.019	0.0528	0.0285
Fabricated metal products	—	0.022	0.009	0.0141	0.0104
Machinery and equipments	0.030	0.033	0.032	0.0374	0.0084
Electrical and electronic mach.	0.050	0.029	0.036	0.0468	0.0346
Transport equipments	—	0.024	0.013	0.0300	-0.0039
Precision instruments	—	-0.025	-0.002	-0.0066	—
Other industrial products	—	as precision	-0.021	0.0027	—
Manufacturing	0.026	0.031	0.019	0.0289	0.0324

Notes:
1. The TFP growth rates for the periods 1961–73 and 1973–82 are available in Liang (1995) and for the period 1961–82 in Liang and Jorgenson (1999).
2. Asterisk (*) denotes the 1969–82 period in Chen and Tang (1990).
3. Liang and Jorgenson (1999) also calculate TFP growth using gross output, which is available in their paper (p. 277, Table 12.2).
4. The TFP growth estimates of Hu and Chan (1999) in this Table are calculated using employees as labour input and 'hours worked' as labour input is also available in their paper (p. 15, Table 1.1).
5. The estimates of DGBAS (2000) are derived using value added with capital and labour inputs. Other results of DGBAS (2000) using gross output are available in Table 20 of the report.

Sources: The TFP growth estimates of Liang (1995) is from pp. 22–23, Table 3; of Chen and Tang (1990) is from p. 580, Table 1; of Liang and Jorgenson (1999) is from p. 277, Table 12.2; of Okuda (1994) is from p. 438, Table I; of Hu and Chan (1999) is from p. 32, Table 3; of DGBAS (2000) is from pp. 104–109, Table 19; of Färe *et al.* (2001) is from p. 1919, Table 5. The last column is from Aw *et al.* (2001, p. 76, Table 8).

Chapter 7

7 Summary and Conclusions

The findings of a number of studies (i.e. Kim and Lau, 1994, Krugman, 1994, Young, 1995, and Collins and Bosworth, 1996), that TFP growth had little to do with the economic miracle achieved by four East Asian countries - Hong Kong, Korea, Singapore and Taiwan - have drawn considerable attention to the controversial debate. The role of TFP growth in East Asia is not only crucial for the future of the region but of particular importance for less developed countries because the successful experience can serve as a model for them to follow. Although there is a consensus on the importance of TFP growth in the process of economic growth, the major concern of the debate is that different methods or assumptions have often led to different results.

Despite the prevailing deficiencies and limitations, such as the assumptions of constant returns to scale, perfect competition and Hicks-neutral technology, growth accounting appears to have been the most popular approach in the literature. Regardless of its wide popularity, growth accounting has recently been questioned as to whether it is appropriate for shedding light on the role of technological progress in the 'East Asian economic miracle' achieved by Hong Kong, Korea, Singapore, and Taiwan (see, Chen, 1997, Felipe, 1999, Nelson and Pack, 1999, Rodrigo, 2000). Furthermore, the synonymous use of TFP growth with technological progress in the earlier growth accounting based studies concludes the East Asian economies achieved insufficient progress in the level of technology. This is certainly flawed.

Using the data from the UNIDO Industrial Statistics Database at the 3-digit level and the varying coefficients frontier model outlined in Chapter 3, this study has examined whether TFP growth played a role in the manufacturing industries of Hong Kong, Japan, Korea, Singapore and Taiwan, respectively. Following Nishimizu and Page (1982), the decomposition of TFP growth into technological progress and change in technical efficiency is successfully carried out. This thesis explicitly distinguishes TFP growth from technological progress as well as recognises the importance of technical efficiency in raising TFP growth.

7.1 Summary of the Main Research Findings

By answering a series of questions proposed by this study, the summary of the main research findings is organised as follows.

- Is there any consensus on this issue of the role of TFP growth in the success of East Asian manufacturing sectors in the literature?

The literature review in Chapter 2 suggests existing empirical results differ from study to study. For Korea's manufacturing sector, the average annual TFP growth estimates vary extensively, ranging from –1.6% in Park and Kwon (1995) to as high as 7.3% in Kim and Han (2001). The empirical TFP studies on Singapore's manufacturing sector seem even more divided. Positive TFP growth was found for Singapore's manufacturing sector in Leung (1997) and Wang and Gan (1994) etc., whereas Tsao (1985) and Young (1995), respectively, claim TFP growth was almost zero or negative. Unlike Singapore, there are relatively more studies confirming Japan and Taiwan experienced various extents of positive TFP growth.

The discrepancies in the literature can be mostly accounted for by the following explanations. First, it is found the methodologies used vary from study to study including the growth accounting, DEA (Malmquist productivity index) and stochastic frontier approaches. Although growth accounting has prevalently been applied in many TFP studies, different specifications of production function may result in different outcomes. Second, different types and sources of data sets may arrive at various outcomes, e.g., firm-level and industry-level (aggregate) data. Third, industrial classifications and aggregations are not always the same even for the same country, as seen in the earlier TFP study reviews. Lastly, with regard to the construction and adjustments of variables, quality improvement embodied in labour and capital inputs have frequently been ignored, leading to overestimation of the extent of TFP growth in some studies. In addition, the use of 'working hours' or 'number of employees' as the measure of labour input certainly gives rise to a variety of conclusions.

- Why does TFP growth differ from technological progress?

Earlier TFP studies repeatedly use TFP growth derived from growth accounting synonymously with technological progress and argue that the TFP progress achieved by East Asian economies was not as extraordinary as previously thought. This is misleading. For firms, TFP growth can be regarded as technological progress *only if* there is no inefficiency while utilising their resources, which is not always possible in the real world. This argument, by extension, supports for the use of the aggregate data in this study. In addition, the existing empirical literature indicates TFP growth can be obtained not only through technological progress but also by improving the technical efficiency with which the chosen technology is applied. Hence, the application that TFP growth is equivalent to technological progress is invalid.

- Why this study favours the use of the varying coefficients frontier model rather than the stochastic frontier approach?

In contrast to the stochastic frontier approach, the varying coefficients frontier model used in this study avoids the assumption of homogeneous behaviour in applying the best practice production technology across firms. Empirically, given the same levels of inputs, data often show that different levels of actual output are obtained, because different firms utilize their resources differently. In order to account for such differences, it is vital to take account of the heterogeneity of firms' behaviour and estimate the variations in both intercepts and slope coefficients across firms and over time for the same firm, namely, reflecting a non-neutral shift in production frontier.

- Did manufacturing industries in East Asia homogeneously statistically apply the best practice production technology?

The specification of the varying coefficients frontier model is explicitly encouraged by the results of the Breusch-Pagan LM test, because the hypothesis of homogeneous industries is statistically rejected for Korea and Singapore's manufacturing industries in most years. Although the results of the Breusch-Pagan LM test do not statistically favour Hong Kong, Japan, and Taiwan's manufacturing industries, in most cases there are certain variations in the estimated coefficients of labour input indicating different applications of their human resources.

- Was TFP growth important in shedding light on the success of East Asian manufacturing sectors?

Ultimately, the analysis of the sources of output growth reveals mixed results. This study finds evidence to strongly support the role of TFP growth in the manufacturing sectors of Hong Kong, Japan, Korea, and Taiwan (only for the 1981–91 period). More specifically, TFP growth contributed as high as 52% to output growth in Japan, roughly 25% in Korea and 38% in Taiwan. Despite a drastic fall in input growth, a small negative output growth was obtained due mostly to considerable TFP growth in Hong Kong.

On the other hand, TFP growth played no role in the Singaporean manufacturing sector, due to the experience of a 22.1% TFP decline over the 1970–97 period, i.e., –0.8% per annum. Regardless of the removal of the 1970–74 period, overall TFP growth over the period 1975–97 remained small at about 8.5%, namely, 0.4% per annum. Without doubt, neither –0.8% nor 0.4% average annual TFP growth rate is comparable with the other four East Asian manufacturing sectors. Overall, it is concluded that the average annual TFP growth of Singapore's manufacturing industries was negative over the 1970–97 period but TFP growth indeed improved in the 1980s and 1990s. Even after vigorous sensitivity tests, the result for Singapore remains pessimistic.

Despite the fact that Hong Kong, Japan, Korea and Taiwan, respectively, enjoyed average annual TFP growth of 2.7%, 2.5%, 3.6% and 2.8% (1981–91), after all, factors accumulation turns out to be the most important factor in shedding light on output growth in the five East Asian manufacturing sectors.

- Did TFP growth slow down in East Asian manufacturing sectors?

With the exception of the Korean and Singaporean manufacturing sectors, TFP growth for Hong Kong, Japan and Taiwan slowed at different degrees. Drawing a linear trend of TFP growth for both Japan and Taiwan's manufacturing sectors, it shows there was a significant slowdown in TFP growth and the extent of TFP decline in Taiwan was evident, especially in the 1990s. For Hong Kong's manufacturing sector, the TFP growth slowdown was relatively insignificant and moderate TFP growth was maintained throughout the period 1976–97.

In contrast to the above three, Korea's manufacturing sector has been gaining TFP growth since 1970 and shows no sign of slowing down. Regardless of the negative TFP growth, Singapore's manufacturing sector gradually reduced the extent of TFP decline indicated by the upward sloping trend of TFP growth.

- What were the sources of TFP growth in East Asian manufacturing sectors?

With further decomposition of TFP growth into technological progress and technical efficiency change, the latter accounted for about 30% of TFP growth in Korea and 10% in Hong Kong. Hence, to some extent, technological progress represented by the adoption of new technology has been more important in raising TFP growth for both Hong Kong and Korea's manufacturing sectors. Due to technical efficiency deterioration, TFP growth in Japan completely stemmed from technological progress. If technical efficiency levels had been maintained, TFP growth in Japan would have been higher.

In contrast to tangible technology, which induces technological progress, technical efficiency improvement caused by a learning-by-doing effect may be interpreted as intangible or *efficiency-based* technology. To some extent, this decomposition analysis reveals that Korean manufacturing industries have outperformed other nations in terms of applying both tangible and intangible technology.

Note that the interpretation of the gloomy findings for Singapore largely depends on the sample period examined. Negative TFP growth over the 1970–97 period was due mainly to a substantial technological decline. But, if the 1970–74 period is excluded, technical efficiency deterioration should be blamed.

A sharp deterioration in technical efficiency was responsible for the slowdown of TFP growth in Taiwan, particularly, in the 1990s. The empirical outcomes have once again substantiated the importance of distinguishing TFP growth from technological progress and stressed the significant role of technical efficiency in the TFP framework.

- What did the nexus reveal between technological progress and structural transformation?

Using the long-term trend analysis, the evolution of technological progress and technical efficiency change has implicitly revealed the nexus between structural transformation and technological progress in the Japan, Korea and Taiwan manufacturing industries. Particularly, these outcomes provide significant policy implications, which are of use to policy makers.

For Japan, the importance of technical efficiency improvement has gradually replaced the role of technological progress in the content of TFP growth. As production technology is in a mature stage in Japan, it is conjectured that technology upgrade becomes costly, and one of the alternatives for maintaining future growth and competitiveness is to engage in improving technical efficiency. More research on the tendency toward technical efficiency improvement rather than technological progress to enhance TFP growth is needed.

The long-term trend analysis indicates that over the 1970–97 period the Korean manufacturing sector not only upgraded technology (technological progress) but also at the same time mastered the new technology quickly (technical efficiency improvement). This helps explain why Korean industries could maintain both technological progress and technical efficiency improvement and enjoy formidable TFP growth.

In contrast to Japan, Singapore's manufacturing industries failed to enhance TFP through technical efficiency improvement. In other words, ignorance of technical efficiency enhancement largely accounted for the negative TFP growth in Singapore's manufacturing industries after the mid-1980s. By looking at the trends of technological progress and technical efficiency improvement, this study points out the continuation of adopting the latest technology and failure to master existing production technology should be responsible for negative TFP growth, because the benefit of advanced technology cannot be entirely realised within a short period of time.

Unlike the other East Asian manufacturing sectors, Taiwan experienced the downward sloping trends of technological progress and technical efficiency change. This finding pessimistically implies the diminishing role played by TFP growth as well as questions future output growth in Taiwan's manufacturing sector.

- Did high-tech manufacturing industries have higher TFP growth?

On the basis of the intrinsic characteristics, the sources of TFP growth for high-tech and low-tech industries are thoroughly compared in this study. The comparison has shown that the proposition, that high-tech industries have higher TFP growth, is empirically valid for Hong Kong but rejected for Japan and Korea. In the cases of Singapore and Taiwan, the proposition is somewhat correct.

- Did TFP growth for high-tech industries stem from technological progress and for low-tech industries from technical efficiency improvement?

With respect to the sources of TFP growth, the hypothesis is in general valid for Singapore's low-tech industries and some of the low-tech industries in Taiwan but invalid for Japan, and Korea. As opposed to the proposition, low-tech industries in Hong Kong unexpectedly experienced technical efficiency deterioration.

- Are the findings of this study reliable and consistent with earlier TFP studies on East Asia?

After vigorous sensitivity tests, the empirical findings of this study remain robust for the controversial case of Singapore's manufacturing sector. No matter how capital depreciate rates and quality adjustment indices are chosen, the reality of negative (or small positive) TFP growth can hardly be reversed. Even several extreme parameters are chosen resulting in small positive TFP growth, which is certainly not comparable with the other East Asian manufacturing sectors.

The findings of this study have generally been consistent with some earlier TFP studies irrespective of different methodologies and sample periods. Yet, the discovery of a TFP decline of 13.8% in Hong Kong's manufacturing sector by Kwong *et al.* (2000) contradicts the finding of 23.3% TFP growth in this study. Unlike other studies for Japan, this study extends the sample period to the 1990s, which was characterised as a period of economic recession and slowdown in TFP growth. Thus, it is understandable that the average annual TFP growth estimates reported in this study are reasonably lower.

The earlier results of TFP studies for Korea are volatile. Regardless of sample periods and methods, for example, the range of TFP growth estimates for Korea was from as low as –1.6% in Park and Kwon (1995) to 7.3% in Kim and Han (2001). Similarly, TFP studies for Singapore report different TFP growth estimates, ranging from –1.0% in Young (1995) to 2.8% in Leung (1997).

This study finds an average annual TFP growth rate of 2.8% for Taiwan's manufacturing sector as a whole over the 1981–91 period, which is parallel to many studies, such as Okuda (1994), Liang and Jorgenson (1999), Färe *et al.* (2001) and Young (1995). For the period 1981–99, this study shows the average annual TFP growth rate fell to only 0.2% implying a dramatic slowdown in TFP growth over the last decade. In contrast, Hu and Chan (1999) and the report by DGBAS (2000) optimistically point out average annual 3.1% and 1.9% TFP growth rates over the periods 1979–96 and 1978–98, respectively.

Finally, it should be noted that some differences arising in comparison with earlier TFP studies is attributable to the specification of the empirical model; more specifically, the model used in this study takes inefficiency into account while others do not.

7.2 LIMITATIONS OF THE ANALYSES

The findings of this study are subject to some limitations that would affect outcomes slightly. First, capital utilisation is implicitly assumed to be constant in this study. If utilisation of capital input is decreasing over time, the growth of capital input will be overstated leading to understatement of TFP growth, and vice versa. Furthermore, due to lack of data, this study adopts employee numbers as labour input instead of working hours. If working hours fell sharply over time, actual labour input could be overestimated resulting in TFP growth being understated slightly.

Second, due to lack of detailed data on the components of factor inputs, labour and capital quality adjustment indices are simply taken from the estimates of Young (1995). However, it is believed that the impact of quality adjustment indices on the TFP growth estimates is minimal as demonstrated by the sensitivity tests.

Third, it is quite common that investment in physical and human capital quite likely depends on the extent of TFP growth. Higher TFP growth always encourages firms to invest more. As a result, the contribution of TFP growth to output growth should be higher if TFP-induced increases in inputs are regarded as part of TFP growth contribution.

Thus, this study does not consider the endogeneity effect of factor inputs while presenting the contribution of TFP growth.

Fourth, due to being beyond of the scope of this research, this study is unable to allow for the specifications of ongoing structural transformations, or trade and industrial policies when assessing TFP growth for the five manufacturing sectors. Obviously, TFP growth in Hong Kong's manufacturing sector is heavily affected by the relocation of manufacturing production to mainland China and diminishing manufacturing share in GDP. The estimated TFP growth for Korean manufacturing industries does not take account of the recent financial crisis and hence requires certain modification before concluding the sustainability of future output growth.

The economic recession in Japan has been on going for over a decade, which definitely generated an impact on the progress of technological upgrade in manufacturing industries. For Taiwan, the official ban on cross-straits investment was lifted in 1991, triggering a massive outflow of capital to mainland China. Especially, for the firms in traditional labour-intensive industries, many transferred their production to mainland China to cope with rising wages and appreciation of the New Taiwan dollar etc. Such impact on TFP growth estimates is quite evident in the 1990s.

7.3 Policy Implications and Future Agenda

After analysing the sources of output growth and TFP growth in Chapters 5 and 6, several policy implications can be drawn from the empirical findings of this study. First, slowdown of TFP growth was prevalent in the East Asian manufacturing sectors apart from Korea. Since TFP growth is critical to the sustainability of East Asian economic growth, this study recommends the adoption of more productive technologies and effective modes of management and organisation. As demonstrated earlier, TFP growth stems from a combination of technological progress and technical efficiency improvement, this study suggests that policy makers may have to allocate limited resources carefully in order to raise TFP growth efficiently through the above two components. In other words, simply pursuing the latest technologies may not be the most cost-effective approach of raising TFP growth. This has often been ignored.

Second, according to a decomposition analysis, technological progress has trended down in Japan and Taiwan as seen in Figures 6.2 and 6.5, which undermined TFP growth significantly in the last decade. If technological decline is due to lack of investment in R&D, it is suggested that implementation of an innovation policy, which offers tax concessions and research grants, may encourage technological innovation and diffusion.

Third, the downward-sloping trend of technical efficiency change in Figures 6.4 and 6.5 reveals there was a considerable slowdown in TFP growth in the manufacturing sectors of Singapore and Taiwan. If technical efficiency deterioration comes from lack of learning-by-doing effects, then policy attention needs to be paid to ensuring the effectiveness of organisational management and job training. In addition, competition policy and market reforms may be useful in promoting the efficiency of production and to some extent in eliminating those who operate inefficiently.

It is hoped the findings of this study can offer more perceptiveness into the sources of TFP growth, facilitate the allocation of resources efficiently and enhance the effectiveness of policy implementation. To fully explore this issue more studies are required. Hence, a future agenda may include the discussion of why Japan's manufacturing industries have shifted their attention to *intangible* technology (technical efficiency improvement) rather than physical technology. Despite the recognition of substantial TFP progress in the 1980s for Taiwan's manufacturing industries, there is little consensus on the role of TFP growth in the 1990s due to the conflicting results between this study and studies by Hu and Chan (1999) and the DGBAS (2000). Hence, it is critical to uncover the reasons for the TFP growth slowdown in Taiwan's manufacturing industries.

After all, on the basis of the UNIDO database and the varying coefficients frontier model, this study has measured the extent of TFP growth for manufacturing industries in the five East Asian economies and analysed the proposed questions in detail. Yet, due to the limited data set, some of the findings may not be conclusive. Therefore, the completion of this study should not be viewed as an end to the research. Rather, based on these findings this study indicates more fieldwork and case studies on individual industries across East Asian countries are required to shed light on the success of the East Asian growth experience.

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